

# NASA TECHNICAL MEMORANDUM

NASA TM X-62,366

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## COMPUTER PROGRAMS FOR ESTIMATING AIRCRAFT TAKEOFF PERFORMANCE IN THREE-DIMENSIONAL SPACE

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July 1974

(NASA-TM-X-62366) COMPUTER PROGRAMS FOR  
ESTIMATING AIRCRAFT TAKEOFF PERFORMANCE IN  
THREE DIMENSIONAL SPACE (NASA) 58 P HC  
\$6.00 58 CSCL 01C



63/02  
46212  
Unclas

N74-30431

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ABSTRACT

A set of computer programs has been developed to estimate the takeoff and initial climb-out maneuver of a given aircraft in three-dimensional space. The program is applicable to conventional, vectored lift and power-lift concept aircraft. The aircraft is treated as a point mass flying over a flat earth with no side slip, and the rotational dynamics have been neglected. The required input is described and a sample case presented.

## INTRODUCTION

A set of computer programs has been developed to estimate the takeoff and initial climb-out maneuver of a given aircraft in three-dimensional space. The program is applicable to conventional, vectored lift and power-lift concept aircraft. The aircraft is treated as a point mass flying over a flat earth with zero sideslip, and the rotational dynamics have been neglected.

The user is required to provide two subroutines which compute the total force coefficients along and normal to the flight path, and determine various required engine characteristics.

This report describes the various subroutines and the required input, the equations used, and the computational techniques involved. Also included is a sample case and a listing of the program.

## NOTATION

Symbol	Fortran name	
$a_t$	T(6), S(10)	acceleration along flight path ( $\text{m/sec}^2$ , $\text{ft/sec}^2$ )
$C_L$	CL	aircraft lift coefficient
$C_D$	CD	aircraft drag coefficient
$C_X$	CX	force coefficient along flight path
$C_Y$	CY	force coefficient normal to flight path and in plane of symmetry of the aircraft
ENP	ENP	number of engines
$g$	G	acceleration due to gravity ( $\text{m/sec}^2$ , $\text{ft/sec}^2$ )
$h$	HABS, S(7)	altitude (m, ft)
$i_w$	EYEW, EYEWNG	incidence of wing (deg)
LF	XLF	load factor
$q$		dynamic pressure ( $\text{N/m}^2$ , $\text{lb/ft}^2$ )

R/C	S(15), ROC, RTCL	rate of climb (m/sec, m/min, ft/sec, ft/min)
R/C <sub>min</sub>	ROCMIN	minimum rate of climb during turning flight (m/min, ft/min)
S	SW, SWING	reference wing area (m <sup>2</sup> , ft <sup>2</sup> )
T	THRUST	thrust, net or gross, per engine (N, lb)
V	T(4), S(4), VEL	aircraft velocity (m/sec, ft/sec)
V <sub>R</sub>	VR	rotation speed, EAS (m/sec, knots)
W	W, WG	aircraft weight (N, lb)
W <sub>f</sub>	WF, WFUEL	fuel flow (N/hr, lb/hr)
x <sub>w</sub>		wind axis coordinate, tangent to flight path (m, ft)
X	S(8)	earth fixed coordinate, along runway (m, ft)
y <sub>w</sub>		wind axis coordinate, perpendicular to x <sub>w</sub> and z <sub>w</sub> (m, ft)
Y	S(9)	earth fixed coordinate, perpendicular to X and Z (m, ft)
z <sub>w</sub>		wind axis coordinate, perpendicular to x <sub>w</sub> and in plane of symmetry (m, ft)
Z	-S(7)	earth fixed coordinate, normal to earth surface (m, ft)
α	ALPHA	angle of attack (deg)
γ	S(5), GAMMA	flight path angle (rad, deg)
δ <sub>f</sub>	DELFD	flap deflection (deg)
δ <sub>s</sub>	DELSPL	spoiler deflection (deg)
θ	THETAF	pitch altitude (fuselage angle) (deg)
μ	MU	rolling coefficient of friction
ν	ANGLE	vectored thrust deflection angle (deg)

$\rho$	RHO	air density (kg/m <sup>3</sup> , slugs/ft <sup>3</sup> )
$\phi$	PHI	roll angle, right wing down positive (deg)
$\psi$	S(6)	heading angle (deg)

#### SUBROUTINE TAKOFF

The subroutine TAKOFF simulates the takeoff and initial climb out maneuver of a given aircraft in three-dimensional space. The program is applicable to conventional, vectored lift and powered lift aircraft. The aircraft is treated as a point mass and the rotational dynamics of the aircraft are neglected. This simplification necessitates an estimation of all rotational rates involved. These rates are either input by the user or are approximated by a finite difference form. In addition, the following assumptions are made:

- flat earth
- constant acceleration of gravity
- zero sideslip angle

The final assumption implies that the velocity vector and the resultant aerodynamic forces are contained in the plane of symmetry (ref. 1).

The takeoff maneuver is divided into four basic segments: ground roll and rotation, liftoff and initial segment climb, acceleration to final climb speed at a constant rate of climb, and finally, the pullup maneuver to establish the final climb speed. Provisions in the program are made for gear retraction, flap retraction, changing of vectored thrust angle and power setting, and changes in heading angle.

The ground roll is made at a specified power setting and flap deflection. When the rotation speed is reached, the aircraft is "rotated" by increasing the angle of attack linearly with time until liftoff occurs or the tail scrape

angle is reached. If the latter occurs, the ground roll is continued with the fuselage angle equal to the tail scrape angle.

The flight path control is obtained by monitoring four dynamic variables - acceleration along the flight path, load factor, fuselage angle (pitch attitude) and rate of climb. The aircraft is not permitted to decelerate and the load factor and fuselage angle are restricted to values less than or equal to a specified maximum value. If any of these conditions are violated, the angle of attack is reduced until all constraints are satisfied. During turning flight, if the rate of climb is less than a specified minimum value, the roll angle is reduced until the time rate of change of the rate of climb is non-negative. In addition, if the time rate of change of the flight path angle is less than  $-1.0$  deg/sec, the roll angle is also reduced.

Once a specified altitude is attained, called the maneuvering altitude, the aircraft is pitched down by a reduction in angle of attack until a specified rate of climb is obtained. The aircraft then accelerates at this rate of climb until the desired final climb speed is reached.

When the final climb speed is attained, the pullup maneuver is executed in order to bring the aircraft to a zero rate of acceleration along the flight path. This maneuver is accomplished by increasing the angle of attack and pulling a load factor of 1.20, which will result in an increase in the rate of climb to a final value at the desired climb speed. It may be necessary to throttle the engines in order to maintain the desired constant climb speed subject to the fuselage angle restriction.

#### Program Inputs

The inputs to subroutine TAKOFF are through the argument list, input by NAMELIST and common blocks /UNIV/ and /AERO/. Either metric or English units

may be used in the program. On the first input data card, starting in col. 1, the word METRIC or ENGLISH should appear, depending on the user's choice of units.

The call to TAKOFF is as follows: CALL TAKOFF (INPC, IDCN, WGROSS, SWING, XENG, VR, VEND) where

INPC    - program control = 1 - input data loaded  
          = 2 - program executed  
          = 3 - data input and program executed  
IDCN    - print control    = 1 - no print out  
          = 9 - print out  
WGROSS - aircraft gross weight (N, lb)  
SWING   - reference wing area ( $m^2$ ,  $ft^2$ )  
XENG    - number of engines  
VR      - rotation speed (m/sec, knots)  
VEND    - final climb speed (m/sec, knots)

All speeds are indicated in air speeds.

There are three namelist inputs to TAKOFF, /NAM1/, /NAM2/ and NAM3/.

The namelist /NAM1/ input variables are as follows:

CDGEAR - drag increment due to gear  
DFLPDT - flap retraction rate (deg/sec)  
DTABS   - temperature increment above standard temperature ( $^{\circ}C$ ,  $^{\circ}F$ )  
DTGR    - time required to retract gear (sec)  
DTPDWN - throttling down rate (percent/sec)  
DTPUP   - throttling advance rate (percent/sec)  
DTVECT - vectored thrust angle reduction rate (deg/sec)  
EYEWNG - wing incidence angle (deg)



HAPT - airport altitude (m, ft)  
 HDT - obstacle height (m, ft)  
 HGR - altitude at which gear retraction is started (m, ft)  
 HMAN - maneuvering altitude (m, ft)  
 HMAX - takeoff termination altitude (m, ft)  
 UM - rolling coefficient of friction  
 NPAGE - number of lines printed per page  
 PMARG - pullup speed margin  
 ROCMIN - minimum rate of climb during turning flight (m/min, fpm)  
 ROLLMX - maximum allowable roll angle (deg)  
 ROLRAT - roll rate (deg/sec)  
 RTCL - rate of climb during accelerate segment (m/min, fpm)  
 THTFly - maximum allowable fuselage angle while airborne (deg)  
 THTS CP - tail scrape angle (deg)  
 XL FMAX - maximum allowable load factor

The user may input all, some, or none of the above input variables. The default values of these input variables are listed below:

GDGEAR = 0.0, DFLPDT = 3.0 deg/sec, DTABS = 0.0° F,  
 DTGR = 5.0 sec, DTPDWN = 5.0 percent/sec,  
 DTPUP = 6.0 percent/sec, DTVECT = 10 deg/sec,  
 EYEWNG = 1.0 deg, HAPT = 0.0 ft, HDT = 35 ft,  
 HGR = 25.0 ft, HMAN = 1000 ft, UM = 0.02,  
 PMARG = 0.04, ROCMDN = 250 fpm, ROLLMX = 15.0 deg,  
 ROLRAT = 5.0 deg/sec, RTCL = 750 fpm,  
 THTFly = 15.0 deg, THTS CP = 10 deg, XL FMAX = 1.15.

Note that all default values contained in the program are in English units.

If the default value of CDGEAR is used, the program will calculate, based on an empirical formula, a value for the gear drag as a function of gross weight and wing area.

The second set of namelist variables, /NAM2/, constitute the flap, throttle and vectored thrust schedules. These are tables that manage the flap setting, power setting and vectored thrust angle as a function of the aircraft speed and altitude. These variables are arrays of dimension 5.

XDELFD (I) - flap deflection (deg)

XHFLAP (I) - flap retraction altitude (m, ft)

SVFLAP (I) - flap retraction speed (m/sec, knots)

XPOWER (I) - power setting

XHPWR (I) - power setting change altitude (m, ft)

XVPWR (I) - power setting change speed (m/sec, knots)

XNV (I) - vectored thrust angle (deg)

XHVECT (I) - vectored thrust angle change altitude (m, ft)

XVVECT (I) - vectored thrust angle change speed (m/sec, knots)

All altitudes are absolute altitudes and all speeds are indicated air speeds.

These schedules are constructed as follows: If the speed or altitude of the aircraft is equal to, say, XVFLAP (I) or XHFLAP (I), respectively, then the flaps are retracted at the rate DFLPDT to the value XDELFD (I). The power setting and vectored thrust angle management work in a similar manner. The power setting may either be increased or decreased. The flap setting and vectored thrust angle setting can only be reduced with altitude or speed. The values of XDELFD (1), XNV (1) and XPOWER (1) are all for the ground run. The

user is permitted four changes in flap, power, vectored thrust angle settings during the airborne portion of the takeoff.

The default values for /NAM2/ are as follows:

- 100 percent throttle throughout takeoff
- 0 degrees vectored thrust
- 15.0 degrees flaps during ground roll, retracted to 5.0 degrees at 250-ft altitude, retraction to 2.0 degrees at 200 knots, and finally, complete retraction at 210 knots.

Again, the user may choose to use all, some, or none of the above schedule values. Note that the default values contained in the program are in English units. No changes to any of these settings are allowed during the pullup maneuver.

The final set of namelist variables, /NAM3/, define the departure headings as functions of absolute altitude and ground distance from the start of takeoff roll point. The heading angle, with values  $-180 \leq \psi \leq 180$ , is positive for right turns proceeding along the flight path. These input variables are arrays of dimension 5.

XHEAD (I) - flight heading (deg)

XHHEAD (I) - heading change altitude (m, ft)

XRANGE (I) - heading change ground distance (km, n.mi.)

The departure heading schedule works in a similar fashion to the flap, power and vectored thrust angle setting schedules. If the absolute altitude or ground distance from the starting point of the takeoff roll is equal to XHHEAD (I) or XRANGE (I), respectively, the aircraft begins to turn to a heading value of XHEAD (I). The runway heading is defined to be a heading

angle of 0 degrees. Changes in aircraft heading are accomplished by increasing or decreasing (for right or left turns, respectively) the roll angle at a rate equal to ROLRAT. The absolute value of the roll angle is restricted to a maximum value of ROLLMX. The roll-out maneuver to establish the required heading is performed by rolling the aircraft back from the banked attitude to zero degrees roll (wings level) at a time such that when the wings are level, the aircraft is on the desired heading. The roll rate for the rollout maneuver is also equal to a value of ROLRAT. The default values for the heading schedule is for a straight out departure (no turns). Four changes in heading angle are permitted during the takeoff.

#### Program Output

The program output consists of a time history of several aircraft and flight path parameters. The output will be in meters or English units, depending on the choice of the user. See the sample listing presented in Appendix B. The output variables are as follows:

TIME	- time from start of takeoff roll (sec)
X DIST	- ground track distance along the earth fixed X coordinate (m, ft)
Y DIST	- ground track distance along the earth fixed Y coordinate (m, ft)
ALT	- aircraft altitude (m, ft)
TAS	- true airspeed along flight path (m/sec, knots)
EAS	- indicated airspeed (m/sec, knots)
MACH NO	- Mach number
ACCEL	- acceleration along flight path (m/sec <sup>2</sup> , ft/sec <sup>2</sup> )
CL	- aerodynamic lift coefficient

CD	- aerodynamic drag coefficient
ALPHA	- angle of attack (deg)
GAMMA	- flight path angle (deg)
R/C	- rate of climb (m/min, fpm)
LOAD FACTOR	- load factor
THRUST	- total thrust, net or gross (N, lb)
FUS. ANG.	- fuselage pitch angle (deg)
ROLL ANGLE	- roll angle (deg)
HEADNG	- heading angle (deg)

In addition, the user may also obtain the following values through the common block /EXCHNG/:

SROLL	- distance to liftoff (m, ft)
S35	- track distance to obstacle height (m, ft)
V35	- speed (EAS) at obstacle height (m/sec, knots)

The program will terminate normally when the end speed is reached (VEND) or when the maximum specified altitude (HMAX) is attained. Abnormal termination will occur under several conditions:

- flight path constraints cannot be met by further reduction  
in angle of attack
- aircraft cannot accelerate at input rate of climb (RTCL)
- aircraft altitude becomes negative
- ground track distance in  $\pm X$  or  $\pm Y$  direction is greater than  
10 n.mi.
- ground run exceeds 90 sec
- elapsed time greater than 300 sec

For further definitions and explanations refer to the listing of TAKOFF and supporting subroutines contained in Appendix C, and the sample case presented in Appendix B.

#### Subroutines ARODYN and ENGINE

The takeoff subroutine described above requires the user to provide two subroutines to compute total force coefficients and determine various required engine characteristics (e.g., thrust and fuel flow per engine). The format and structure of these subroutines is left to the discretion of the user. The units used in these subroutines should be the same as those of the input data.

##### I. Subroutine ARODYN

This subroutine computes the total force coefficients along the flight path and normal to the flight path in the plane of symmetry as a function of angle of attack and thrust. A force coefficient in a particular direction  $\vec{e}_s$  is defined to be the sum of all aerodynamic and propulsion system forces in that particular direction, divided by the dynamic pressure times the wing area.

$$C_s \triangleq \frac{\vec{e}_s \cdot \Sigma \vec{F}}{qS}$$

The transfer of the various computer variable values to and from subroutine ARODYN is through labeled common blocks /UNIV/ and /AERO/. Of primary concern is the common block /AERO/:

```
COMMON /AERO/ VEL, QS, HABS, THRUST, TVECT, ANGLE, DELFD, DELSPL, ALPHA,  
              CS, CY, CL, CD, RHO, GRCD, IFAST
```

The input variables from TAKOFF are:

VEL            - aircraft velocity along flight path (m/sec, ft/sec)

QS	- dynamic pressure times wing area (N, lbs)
HABS	- absolute altitude of aircraft (m, ft)
THRUST	- thrust (net or gross) per engine (N, lbs)
TVECT	- total vectored thrust (N, lbs)
ANGLE	- angle of vectored thrust relative to aircraft center line, positive down (deg)
DELF	- flap deflection (deg)
DELSPL	- spoiler deflection (deg)
ALPHA	- angle of attack (deg)
RHO	- air density ( $\text{kg/m}^3$ , slugs/ft <sup>3</sup> )
GRCD	- drag increment due to gear

The return from ARODYN should be:

CX	- total force coefficient along flight path
CY	- total force coefficient normal to flight path in plane of symmetry

The output variables CL and CD are provided to the user as a means to distinguish between pure aerodynamic coefficients and total force coefficients. The output variables CL and CD are printed out in the time history, but are not used in the actual calculations. If desired, in subroutine ARODYN, CL and CD may be directly equated to CY and CX, respectively.

There is a certain amount of redundancy among some of the input variables. The user may utilize only those variables he desires and disregard the others. Due to the wide range of velocities encountered during the takeoff, there will be a correspondingly large variation in the magnitude of the force coefficients which must be accommodated in subroutine ARODYN.

## II. Subroutine ENGINE

This subroutine provides the various propulsion data to subroutines TAKOFF and ARODYN.

The inputs to subroutine ENGINE are through the argument list and labeled common blocks /AERO/ and /UNIV/.

The call to ENGINE is as follows:

CALL ENGINE (ALT, DTABS, EN, PWRSET, WFUEL, KENG)

where

ALT	- aircraft altitude (m, ft)
DTABS	- temperature increment above standard temperature (°C, °F)
EN	- aircraft Mach number
PWRSET	- power setting (see below)
WFUEL	- fuel flow (N/hr, lbs/hr)
KENG	- engine control parameter = 0

The variable PWRSET is defined to be:

$$PWRSET = \frac{\text{net thrust}}{\text{net thrust available}}$$

and is the parameter used in controlling the thrust level. It is used for power setting management during the takeoff.

The user may choose to work with either the gross thrust per engine or the net thrust per engine, provided he uses the variable THRUST properly in the calculation of the total force coefficients. For example, when using gross thrust per engine, the ram drag must be included in the total summation of forces. If the gross thrust vector and ram drag vector can be considered collinear, the user may choose instead to work simply with the net thrust.

Refer to the sample case presented for an illustration of subroutines ARODYN and ENGINE.



## REFERENCES

1. Williams, J.: Aircraft Performance - Prediction Methods and Optimization, AGARD-LS-56, 1972.
2. Miele, Angelo: Flight Mechanics, Vol. 1, Addison-Wesley Publishing Company, Inc., 1962.
3. Bowles, Jeff V., and Galloway, Thomas L.: Computer Programs for Estimating Aircraft Takeoff and Landing Performance, NASA TM X-62,333, July 1973.

## APPENDIX A

### EQUATIONS

1. Equation of motion during ground roll

$$dV/dt = (g/W) [-W\mu + qS(C_{y\mu} - C_x)]$$

2. Equation of motion along flight path

$$dV/dt = (g/W)(-C_x qS - W \sin \gamma)$$

3. Equation of motion normal to flight path and in the plane of symmetry

$$d\psi/dt \sin \phi \cos \gamma + d\gamma/dt \cos \phi = (g/WV)(C_y qS - W \cos \gamma \cos \phi)$$

4. Equation of motion normal to the flight path and normal to plane of symmetry

$$-d\psi/dt \cos \phi \cos \gamma + d\gamma/dt \sin \phi = (g/WV) \sin \phi \cos \gamma$$

where

$g$  = gravity constant

$W$  = aircraft weight

$q$  = dynamic pressure

$S$  = wing area

$\gamma$  = flight path angle

$\psi$  = heading angle

$\phi$  = roll angle

$V$  = aircraft velocity

$C_x$  = total force coefficient along flight path

$C_y$  = total force coefficient normal to flight path and in plane of symmetry

The coordinate systems used are presented in figure 1. The XYZ is the right handed earth fixed coordinate system, with the X-axis aligned with the runway. The Z axis is vertical and positive downward. The wind axis system is defined as follows: the  $x_w$  axis is tangent to the flight path and positive in the direction of flight; the  $z_w$  is normal to the  $x_w$  axis, in the plane of symmetry of the aircraft, and is positive downward in level flight; the  $y_w$  axis is normal to the  $x_w$  and  $z_w$  axis in the right handed sense. The  $x, y, z$  coordinate system is the translation of the XYZ axis system to the location of the point mass representation of the aircraft (ref. 2).

In order to make the system of equations of motion more amenable to numerical integration, the equations are manipulated in order to obtain explicit relations for the time rates of change of the velocity, flight path angle and heading angle.

The equation for  $dV/dt$  is already in the desired form. Note that the acceleration along the flight path is independent of the roll attitude. To obtain an expression for  $d\gamma/dt$  alone, equation 3 is multiplied by  $\cos \phi$ , equation 4 multiplied by  $\sin \phi$  and the resulting equations subtracted to give:

$$5. \quad d\gamma/dt = [g/(WV)] (C_y qS \cos \phi - W \cos \gamma)$$

An expression for  $d\psi/dt$  alone is obtained in a similar manner:

$$6. \quad d\psi/dt = [g/(WV \cos \gamma)] C_y qS \sin \phi$$

The system of equations 2, 5, and 6 are then numerically integrated using the Adams-Moulton fixed step-size method.

7. Load factor

$$XLF = \frac{qSC_y}{W}$$

8. Constant rate of climb equation

$$\text{Rate of climb} \triangleq \text{ROC} = V \sin \gamma$$

For ROC to be constant with time,

$$\frac{d\text{ROC}}{dt} \equiv 0$$

or,

$$\frac{d\text{ROC}}{dt} = \frac{d}{dt} (V \sin \gamma) = \frac{dV}{dt} \sin \gamma + V \cos \gamma \frac{d\gamma}{dt} = 0$$

Substituting for terms  $dV/dt$  and  $d\gamma/dt$  from equations 2 and 5, and simplifying:

$$qS(C_y \cos \gamma \cos \phi - C_x \sin \gamma) - W = 0$$

9. Rotational rate approximations by finite difference

$$\theta = \gamma + \alpha - i_w$$

where

$\theta$  - pitch attitude (fuselage angle)

$\gamma$  - flight path angle

$\alpha$  - angle of attack

$i_w$  - incidence of wing

Differentiating with respect to time we obtain:

$$\frac{d\theta}{dt} = \frac{d\alpha}{dt} + \frac{d\gamma}{dt}$$

where  $\frac{d\gamma}{dt}$  is given by equation 5.

$\frac{d\alpha}{dt}$  is approximated by the finite difference form:

$$\frac{d\alpha}{dt} = (\alpha_{\text{now}} - \alpha_{\text{past}}) / \Delta t$$

where

$\alpha_{\text{now}}$  = current value of the angle of attack

$\alpha_{\text{past}}$  = previous value of angle of attack

$\Delta t$  = integration time interval

#### 10. Roll-out control equation

As the desired heading angle  $\psi_f$  is approached with the aircraft banked at some angle of roll  $\phi_T$ , the roll angle is reduced at the rate of roll ROLRAT to zero in such a way that when the wings are level (implying  $d\psi/dt = 0$ ),  $\psi = \psi_f$ . To perform this roll-out maneuver, an open loop type control procedure is used. The problem is to determine at what heading angle  $\psi$  the roll-out should be initiated.

From equation 6

$$\frac{d\psi}{dt} = \frac{gqSC_y}{WV \cos \gamma} \sin \phi \approx \frac{gqSC_y}{WV \cos \gamma} \phi$$

for moderate angles of bank.

Using a finite difference form approximation for  $d\psi/dt$  and the definitions of figure 2,

$$\frac{d\psi}{dt} \approx \frac{\psi_f - \psi}{\Delta t} = \frac{\Delta\psi}{t_f} = \frac{gqSC_y}{WV \cos \gamma} \phi_{\text{ave}}$$

It is desired that the time average of  $\phi$  over the time interval  $0 < t' < t_f$  equals  $\phi_{\text{ave}}$ , where

$$\phi = \phi_T + \frac{d\phi}{dt} t', \quad \frac{d\phi}{dt} \text{ being constant}$$

therefore

$$\phi_{\text{ave}} t_f = \int_0^{t_f} \left( \phi_T + \frac{d\phi}{dt} t' \right) dt'$$

or, upon integration,

$$10a. \quad \frac{\Delta\psi}{t_f} \frac{WV \cos \gamma}{gqSC_y} t_f = \phi_T t_f + \frac{1}{2} \frac{d\phi}{dt} t_f^2$$

Now, for  $\phi(t_f) = 0$ ,

$$\frac{d\phi}{dt} = \frac{0 - \phi_T}{t_f} = - \frac{\phi_T}{t_f}$$

Solving for  $t_f$  and substituting in equation 10a

$$10b. \quad |\Delta\psi| = \frac{\phi_T^2 gqSC_y}{2(d\phi/dt)WV \cos \gamma}$$

The value of  $\Delta\psi$  is monitored during turning flight, and whenever  $|\psi_f - \psi| \leq |\Delta\psi|$ , the roll-out maneuver is begun. This estimate of  $\Delta\psi$  is not exact, since the velocity  $V$  and the flight path angle  $\gamma$  will change over the time period  $t_f$ , but for moderate roll angles and roll rates,  $t_f$  will be small, and hence changes in  $V$  and  $\gamma$  correspondingly small.

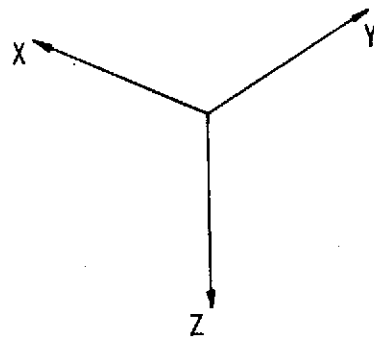
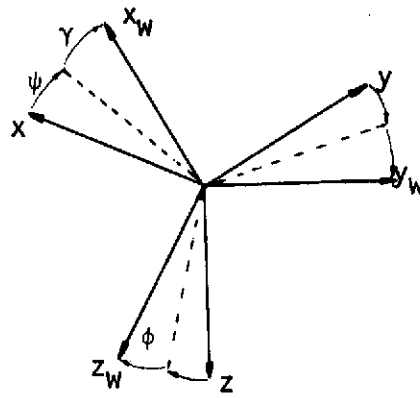
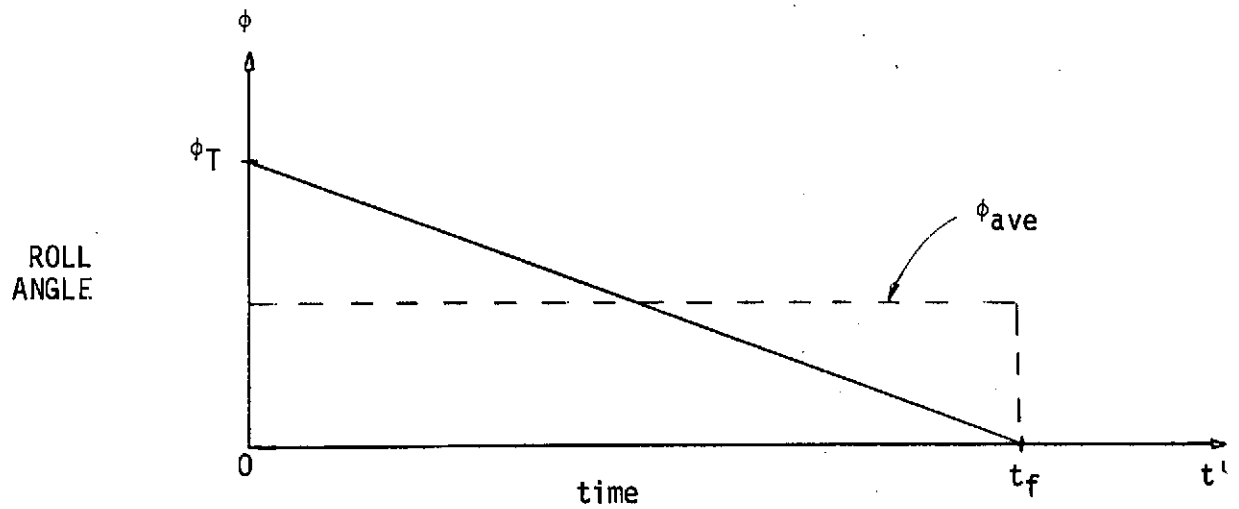


Figure 1.- Coordinate axis systems



$t'=0$  - start of rollout maneuver

$$\phi(0) = \phi_T, \phi(t_f) = 0$$

Figure 2.- Rollout maneuver parameters

## APPENDIX B

### SAMPLE CASE

Shown below is an example of the input, calling format, subroutines ARODYN and ENGINE, and the print out obtained from the takeoff program.

The main calling program TEST1 is set up to do the takeoff of a Boeing 727-200. The required common blocks are shown, but others may be added if needed. This example was done in English units.

The input was as follows:

ENGLISH

```
$NAM1  NPAGE = 48, RTCL = 550.,  
      THTFLY = 20., HMAN = 2000.,  
      ROLLMX = 30., ROCMIN = 500.  $END  
$NAM2  XPOWER(2) = 0.75, XHPWR(2) = 750.,  
      XPOWER(3) = 0.95, XHPWR(3) = 1750.  $END  
$NAM3  XHEAD(1) = 45., XHHEAD(1) = 800.,  
      XHEAD(2) = -15., XHHEAD(2) = 2250.  $END
```

Subroutine ARODYN calculates the lift and drag coefficients of the 727-200 as a function of angle of attack, flap and spoiler deflection. The increments of lift and drag due to flaps is determined by a table look-up format. Once the lift and drag coefficients are computed, the thrust components, normalized by dynamic pressure times wing area (QS), are added in to determine the total force coefficients CX and CY.

Subroutine ENGINE computes the thrust and fuel flow of the JT8D engine, based on a simplified model. The thrust lapse is assumed to be linear with Mach number, and the fuel flow assumed linear with power setting.



This particular run was made on the Lawrence Berkeley Laboratory CDC 7600, requiring a field length of 41700 words to load and 2.47 sec to execute.

TEST1

```

      PROGRAM TEST1(INPUT,OUTPUT,TAPES=INPUT,TAPE6=OUTPUT)
      COMMON /UNIV/ NPC ,NSC ,IDC ,H ,ST ,R ,W ,
1WF ,EM ,VMO ,EMMO ,ALPHLO,CLALPH,SW ,AR ,B ,
2LEYEW ,ENP ,TA ,WG ,WGS ,KWRITE,DLHC4
      3,KSIZE
      COMMON /AERO/ VEL,GS,HABS,THRUST,TVECT, ANGLE,DELFD,DELSPL,ALPHA,
9CX,CY,CL,CD,RHO,GRCD,IFAST
      WG = 172000.
      3 SWING = 1720.
      5 ENP = 3.0
      6 DELSPL = 0.0
      7 RHO = 0.0023
      10 SW = SWING
      12 W = WG
      14 CALL TAKOFF(3,9,WG,SW,3.0,135,0,250.)
      22 END

```

PROGRAM LENGTH INCLUDING I/O BUFFERS

01116

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

BLOCK NAMES AND LENGTHS

UNIV = 000030/01 AERO = 000020/02

VARIABLE ASSIGNMENTS

DELSPL = 000007/02 ENP = 000021/01 RHO = 000015/02 SW = 000015/01 SWING = 000047 W = 000006/01  
WG = 000023/01

START OF CONSTANTS=000025 TEMPS--000045 INDIRECTS=000047

7600 COMPILATION -- RUN76 LEVEL 9R 74/07/15,

ROUTINE COMPILES IN 044000

# ARODYN

```

SUBROUTINE ARODYN
  REAL NU
  COMMON /UNIV/ NPC ,NSC ,IDC ,H ,ST ,R ,W ,
  1NF ,EM ,VMO ,EMMO ,ALPHLO,CLALPH,SW ,AR ,B ,
  2EYEW ,ENP ,TA ,WG ,WGS ,KWRITE,OLMC4
  3,KSIZE
  COMMON /AERO/ VEL,QS,HABS,THRUST,TVECT, ANGLE,DELFD,DELSPL,ALPHA,
  9CX,CY,CL,CD,RHO,GRCD,IFAST
  DIMENSION XDELFD(6),XDELCL(4),XDELCD(6),XVDEL6(6)
  DATA XDELFD/0.0,5.0,10.,15.,20.,25./
  DATA XDELCL/0.0,0.186,0.347,0.482,0.60,0.702/
  DATA XDELCD/0.0,.0148,.0295,.0451,.0607,.0837/
  DATA XVDEL6/1.0,.995,.990,.980,.970,.955/
  CALL ITRLN(XDELFD,XDELCD,DELFD,DELCDF,6)
  CALL ITRLN(XDELFD,XDELCL,DELFD,DELCDF,6)
  CALL ITRLN(XDELFD,XVDEL6,DELFD,VDEL6,6)
  5
  11
  17
  20
  22
  23
  25
  26
  30
  32
  36
  40
  47
  51
  53
  55
  63
  72
  72
  END
  SA5 = 0.016
  CLALPH = 4.5
  ALPHLO = -1.5
  SA7 = 0.0546
  SIGMA = 0.6
  DCLSP = 0.31*(DELSPL/90.)
  DCDSPL = 0.12*(DELSPL/90.)
  CL = CLALPH*(ALPHA - ALPHLO)*.017453 + DELCLF
  CL = CL - DCLSP
  CD = SA5 + DELCDF + (SA7/VDEL6)*(CL - SIGMA*DELCDF)**2 + GRCD
  CD = CD + DCDSPL
  1 ALPHX = ALPHA + .0174533
  IF(QS.EQ. 0.0)QS = 0.1
  CX = CD - THRUST*ENP*COS(ALPHX)/QS
  CY = CL + THRUST*ENP*SIN(ALPHX)/QS
  RETURN
  END

```

## SUBPROGRAM LENGTH

00167

## FUNCTION ASSIGNMENTS

## STATEMENT ASSIGNMENTS

1 - 000052

## BLOCK NAMES AND LENGTHS

UNIV - 000030/01 AERO - 000020/02

## VARIABLE ASSIGNMENTS

ALPHA - 000010/02	ALPHLO - 000013/01	ALPHX - 000166	CD - 000014/02	CL - 000013/02	CLALPH - 000014/01
CX - 000011/02	CY - 000012/02	DCDSPL - 000165	DCLSP - 000164	DELCDF - 000156	DELCDF - 000157
DELFD - 000006/02	DELSPL - 000007/02	ENP - 000021/01	GRCD - 000016/02	NU - 000125	QS - 000001/02
SA5 - 000161	SA7 - 000162	SIGMA - 000163	THRUST - 000003/02	VDEL6 - 000160	XDELCD - 000142
XDELCL - 000134	XDELFD - 000126	XVDEL6 - 000150			

START OF CONSTANTS-000075 TEMPS--000112 INDIRECTS-000125

# ENGINE

```

SUBROUTINE ENGINE(ALT,DYABS,EN,PWRSET,WFUEL,KENG)
COMMON /AERO/ VEL,DS,HABS,THRUST,TVECT, ANGLE,DELPD,DELSPL,ALPHA,
9CX,CY,CL,CD,RHO,GRCD,IFAST
IF(KENG,FO. )GO TO 10
11 TO = 14000.
12 THRUST = (TO - 6.0*EN*1100.)*PWRSET
16 11 WFUEL = THRUST*0.63*PWRSET
20 RETURN
21 10 PWRSET = THRUST/(TO - 6.0*EN*1100.)
25 GO TO 11
26 END

```

## SUBPROGRAM LENGTH

00043

## FUNCTION ASSIGNMENTS

### STATEMENT ASSIGNMENTS

10 - 000022 11 - 000017

### BLOCK NAMES AND LENGTHS

AERO - 000020/01

### VARIABLE ASSIGNMENTS

THRUST - 000003/01 TO - 000042

START OF CONSTANTS=000031 TEMPS--000036 INDIRECTS=000042

7600 COMPILE -- RUN76 LEVEL 98 74/07/15.

ROUTINE COMPILES IN 044000

\*\* INPUTS TO TAKE OFF = ALTITUDE = 0.0 TEMPERATURE = 59.0 DEG.

#### A/C CHARACTERISTICS

GROSS RAMP WT. = 172000 WING AREA = 1720 STATIC SEA LEVEL THRUST = 14000  
WING LOADING = 100.0 THRUST/WEIGHT = .244

#### A/C PARAMETERS,

NO. ENGINES = 3.0 CDGEAR = .0287 EYEWNG = 1.0 TAIL SCRAPE ANGLE = 10.0

#### FLIGHT PATH CONTROL PARAMETERS

MAX LOAD FACTOR = 1.10 GEAR RETRACTION ALT. = 25.0 MAX FLOOR ANGLE = 20.0  
MANEUVER ALT. = 2000 ACCELERATE RATE OF CLIMB = 550

#### PARAMETER VARIATION RATES

DADT = 1.0 DFLPDY = 3.0 DTGR = 5.0 DTPDWN = 5.0  
DTDUP = 6.0 DTVECT = 10.0

#### POWER, VECTORED THRUST, AND FLAP SCHEDULES

##### THROTTLE/POWER SETTING

PWRSET	1.00	.75	.95	1.00	1.00
SPEED	0.0	0.0	0.0	999.0	999.0
ALTITUDE	0	750	1750	0	0

##### VECTORED THRUST ANGLE

ANGLE	0.0	0.0	0.0	0.0	0.0
SPEED	0.0	999.0	999.0	999.0	999.0
ALTITUDE	0	0	0	0	0

##### FLAP DEFLECTION ANGLE

DEFLD	15.0	5.0	2.0	0.0	0.0
SPEED	0.0	0.0	200.0	210.0	0.0
ALTITUDE	0	250	0	0	0

ALL SPEEDS ARE INDICATED AIR SPEEDS AND ALL ALTITUDES ARE ABSOLUTE ALTITUDES

#### DEPARTURE HEADINGS

RANGE	100.0	100.0	100.0	100.0	100.0
ALTITUDE	800.0	2250.0	99999.0	99999.0	99999.0
HEADING	45.0	-15.0	0.0	0.0	0.0

TAKEOFF (ELEVATION = 0 FT)

TIME (SEC)	X DIST (FEET)	Y DIST (FEET)	ALT (FEET)	TAS (KTS)	EAS (KTS)	MACH NO.	ACCEL (FPS2)	CL	CD	ALPHA (DEG)	GAMMA (DEG)	R/C (FPM)	LOAD FACT	THRUST (LBS)	FUS. ANG.	ROLL ANGLE	HEADING (DEG)
0.0	0.0	0.0	0.0	0.0	0.0	0.000	7.22	.678	.0982	1.00	0.00	0.0	0.00	42000	0.0	0.0	0.0
1.0	3.6	0.0	0.0	4.3	4.3	.006	7.20	.678	.0982	1.00	0.00	0.0	0.00	41885	0.0	0.0	0.0
2.0	14.4	0.0	0.0	8.5	8.5	.012	7.17	.678	.0982	1.00	0.00	0.0	0.00	41758	0.0	0.0	0.0
3.0	32.4	0.0	0.0	12.8	12.8	.019	7.14	.678	.0982	1.00	0.00	0.0	0.00	41631	0.0	0.0	0.0
4.0	57.5	0.0	0.0	17.0	17.0	.025	7.10	.678	.0982	1.00	0.00	0.0	0.00	41504	0.0	0.0	0.0
5.0	89.7	0.0	0.0	21.2	21.2	.031	7.06	.678	.0982	1.00	0.00	0.0	0.00	41379	0.0	0.0	0.0
6.0	129.0	0.0	0.0	25.3	25.3	.038	7.02	.678	.0982	1.00	0.00	0.0	0.00	41254	0.0	0.0	0.0
7.0	175.3	0.0	0.0	29.5	29.5	.044	6.98	.678	.0982	1.00	0.00	0.0	0.00	41130	0.0	0.0	0.0
8.0	228.6	0.0	0.0	33.6	33.6	.050	6.93	.678	.0982	1.00	0.00	0.0	0.00	41006	0.0	0.0	0.0
9.0	288.8	0.0	0.0	37.7	37.7	.056	6.88	.678	.0982	1.00	0.00	0.0	0.00	40884	0.0	0.0	0.0
10.0	355.9	0.0	0.0	41.8	41.8	.063	6.83	.678	.0982	1.00	0.00	0.0	0.00	40762	0.0	0.0	0.0
11.0	429.8	0.0	0.0	45.8	45.8	.069	6.78	.678	.0982	1.00	0.00	0.0	0.00	40642	0.0	0.0	0.0
12.0	510.5	0.0	0.0	49.8	49.8	.075	6.72	.678	.0982	1.00	0.00	0.0	0.00	40522	0.0	0.0	0.0
13.0	597.9	0.0	0.0	53.7	53.7	.081	6.66	.678	.0982	1.00	0.00	0.0	0.00	40403	0.0	0.0	0.0
14.0	692.0	0.0	0.0	57.7	57.7	.087	6.60	.678	.0982	1.00	0.00	0.0	0.00	40286	0.0	0.0	0.0
15.0	792.6	0.0	0.0	61.5	61.5	.092	6.53	.678	.0982	1.00	0.00	0.0	0.00	40169	0.0	0.0	0.0
16.0	899.8	0.0	0.0	65.4	65.4	.098	6.47	.678	.0982	1.00	0.00	0.0	0.00	40054	0.0	0.0	0.0
17.0	1013.5	0.0	0.0	69.2	69.2	.104	6.40	.678	.0982	1.00	0.00	0.0	0.00	39940	0.0	0.0	0.0
18.0	1133.6	0.0	0.0	73.0	73.0	.110	6.33	.678	.0982	1.00	0.00	0.0	0.00	39827	0.0	0.0	0.0
19.0	1260.0	0.0	0.0	76.7	76.7	.115	6.25	.678	.0982	1.00	0.00	0.0	0.00	39715	0.0	0.0	0.0
20.0	1392.6	0.0	0.0	80.4	80.4	.121	6.18	.678	.0982	1.00	0.00	0.0	0.00	39605	0.0	0.0	0.0
21.0	1531.4	0.0	0.0	84.0	84.0	.126	6.10	.678	.0982	1.00	0.00	0.0	0.00	39496	0.0	0.0	0.0
22.0	1676.4	0.0	0.0	87.6	87.6	.132	6.03	.678	.0982	1.00	0.00	0.0	0.00	39388	0.0	0.0	0.0
23.0	1827.3	0.0	0.0	91.1	91.1	.137	5.95	.678	.0982	1.00	0.00	0.0	0.00	39282	0.0	0.0	0.0
24.0	1984.2	0.0	0.0	94.6	94.6	.143	5.87	.678	.0982	1.00	0.00	0.0	0.00	39177	0.0	0.0	0.0
25.0	2147.0	0.0	0.0	98.1	98.1	.148	5.79	.678	.0982	1.00	0.00	0.0	0.00	39073	0.0	0.0	0.0
26.0	2315.6	0.0	0.0	101.5	101.5	.153	5.71	.678	.0982	1.00	0.00	0.0	0.00	38971	0.0	0.0	0.0
27.0	2489.8	0.0	0.0	104.9	104.9	.158	5.62	.678	.0982	1.00	0.00	0.0	0.00	38871	0.0	0.0	0.0
28.0	2669.7	0.0	0.0	108.2	108.2	.163	5.54	.678	.0982	1.00	0.00	0.0	0.00	38772	0.0	0.0	0.0
29.0	2855.2	0.0	0.0	111.4	111.4	.168	5.46	.678	.0982	1.00	0.00	0.0	0.00	38674	0.0	0.0	0.0
30.0	3046.1	0.0	0.0	114.6	114.6	.173	5.37	.678	.0982	1.00	0.00	0.0	0.00	38578	0.0	0.0	0.0
31.0	3242.3	0.0	0.0	117.8	117.8	.178	5.29	.678	.0982	1.00	0.00	0.0	0.00	38483	0.0	0.0	0.0
32.0	3443.9	0.0	0.0	120.9	120.9	.182	5.20	.678	.0982	1.00	0.00	0.0	0.00	38390	0.0	0.0	0.0
33.0	3650.7	0.0	0.0	123.9	123.9	.187	5.12	.678	.0982	1.00	0.00	0.0	0.00	38299	0.0	0.0	0.0
34.0	3862.5	0.0	0.0	126.9	126.9	.191	5.03	.678	.0982	1.00	0.00	0.0	0.00	38209	0.0	0.0	0.0
35.0	4079.4	0.0	0.0	129.9	129.9	.196	4.94	.678	.0982	1.00	0.00	0.0	0.00	38120	0.0	0.0	0.0
36.0	4301.3	0.0	0.0	132.8	132.8	.200	4.86	.678	.0982	1.00	0.00	0.0	0.00	38033	0.0	0.0	0.0
ROTATION (TIME = 36.8			AND TAS = 135.1			EAS = 135.1)											
37.0	4528.0	0.0	0.0	135.6	135.6	.205	4.76	.694	.0989	1.20	0.00	0.0	0.00	37948	.2	0.0	0.0
38.0	4759.4	0.0	0.0	138.4	138.4	.209	4.63	.773	.1028	2.20	0.00	0.0	0.00	37864	1.2	0.0	0.0
39.0	4995.5	0.0	0.0	141.1	141.1	.213	4.47	.851	.1074	3.20	0.00	0.0	0.00	37783	2.2	0.0	0.0
40.0	5236.1	0.0	0.0	143.7	143.7	.217	4.29	.930	.1127	4.20	0.00	0.0	0.00	37705	3.2	0.0	0.0
41.0	5480.9	0.0	0.0	146.2	146.2	.221	4.10	1.008	.1186	5.20	0.00	0.0	0.00	37631	4.2	0.0	0.0
42.0	5729.8	0.0	0.0	148.6	148.6	.224	3.88	1.087	.1252	6.20	0.00	0.0	0.00	37560	5.2	0.0	0.0
43.0	5982.6	0.0	0.0	150.8	150.8	.228	3.63	1.165	.1326	7.20	0.00	0.0	0.00	37493	6.2	0.0	0.0
LIFTOFF (TIME = 43.9			DIST = 6213.3			TAS = 152.7		EAS = 152.7)									
44.0	6239.1	0.0	.0	152.9	152.9	.231	3.35	1.244	.1406	8.20	.01	3.0	1.02	37430	7.2	0.0	0.0
45.0	6498.8	0.0	.8	154.7	154.7	.234	2.79	1.311	.1479	9.05	.46	126.2	1.10	37374	8.5	0.0	0.0
46.0	6761.4	0.0	4.6	156.2	156.2	.236	2.39	1.287	.1453	8.75	1.15	318.6	1.10	37328	8.9	0.0	0.0
47.0	7026.2	0.0	11.5	157.5	157.5	.238	2.00	1.267	.1431	8.50	1.84	511.7	1.10	37288	9.3	0.0	0.0
48.0	7293.0	0.0	21.6	158.6	158.6	.240	1.62	1.248	.1410	8.25	2.52	707.1	1.10	37255	9.8	0.0	0.0

# TAKEOFF CONTINUED

TIME (SEC)	X DIST (FEET)	Y DIST (FEET)	ALT (FEET)	TAS (KTS)	EAS (KTS)	MACH NO.	ACCEL (FPS <sup>2</sup> )	CL	CD	ALPHA (DEG)	GAMMA (DEG)	R/C (PPH)	LOAD FACT	THRUST (LBS)	FUS. ANG.	ROLL ANGLE	HEADING (DEG)
GEAR RETRACTION STARTED AT 48.3 SEC, COMPLETE AT 53.3 SEC DISTANCE TO OBSTACLE HEIGHT = 7560.6 SCREEN SPEED(EAS) = 159.4																	
49.0	7841.3	0.0	35.0	159.5	159.4	.241	1.33	1.236	.1363	8.10	3.20	903.3	1.10	37228	10.3	0.0	0.0
50.0	7830.7	0.0	51.7	160.2	160.1	.242	1.09	1.228	.1297	8.00	3.89	1101.2	1.10	37206	10.9	0.0	0.0
51.0	8101.0	0.0	71.8	160.7	160.6	.243	.87	1.220	.1232	7.90	4.58	1300.0	1.10	37188	11.5	0.0	0.0
52.0	8371.9	0.0	95.1	161.2	161.0	.244	.64	1.212	.1166	7.80	5.27	1500.9	1.10	37174	12.1	0.0	0.0
53.0	8643.1	0.0	121.8	161.5	161.2	.244	.42	1.208	.1105	7.75	5.97	1702.3	1.10	37164	12.7	0.0	0.0
54.0	8914.4	0.0	151.8	161.7	161.5	.245	.09	1.208	.1082	7.75	6.67	1902.4	1.10	37158	13.4	0.0	0.0
55.0	9185.8	0.0	184.9	161.7	161.2	.245	.00	1.142	.1016	6.90	7.19	2049.4	1.03	37157	13.1	0.0	0.0
56.0	9456.3	0.0	219.6	161.7	161.2	.245	.00	1.110	.0987	6.50	7.35	2095.5	1.00	37156	12.8	0.0	0.0
FLAPS RETRACTED TO 5.0 DEG. IN 3.3 SEC.																	
57.0	9727.1	0.0	254.6	161.7	161.1	.245	.02	1.102	.0974	6.50	7.39	2108.8	1.00	37156	12.9	0.0	0.0
58.0	9997.9	0.0	289.8	161.7	161.1	.245	.13	1.100	.0921	7.50	7.43	2119.4	1.00	37154	13.9	0.0	0.0
59.0	10268.9	0.0	325.3	161.8	161.1	.245	.24	1.091	.0870	8.50	7.47	2131.5	.99	37150	15.0	0.0	0.0
60.0	10540.0	0.0	360.8	162.0	161.2	.245	.37	1.072	.0821	9.50	7.44	2126.8	.98	37144	15.9	0.0	0.0
61.0	10811.5	0.0	396.3	162.2	161.3	.246	.15	1.128	.0875	10.50	7.51	2149.4	1.04	37138	17.0	0.0	0.0
62.0	11083.0	0.0	433.0	162.2	161.2	.246	.00	1.117	.0862	10.35	7.86	2247.9	1.03	37137	17.2	0.0	0.0
63.0	11354.4	0.0	470.8	162.2	161.1	.246	.01	1.093	.0837	10.05	8.00	2287.6	1.00	37136	17.0	0.0	0.0
64.0	11625.7	0.0	509.1	162.2	161.0	.246	.01	1.085	.0828	9.95	8.04	2300.7	.99	37135	17.0	0.0	0.0
65.0	11897.0	0.0	547.5	162.2	160.9	.246	.00	1.085	.0828	9.95	8.06	2306.0	.99	37134	17.0	0.0	0.0
66.0	12168.3	0.0	585.9	162.2	160.9	.246	.00	1.085	.0828	9.95	8.07	2306.9	.99	37134	17.0	0.0	0.0
67.0	12439.6	0.0	624.8	162.2	160.8	.246	.00	1.085	.0828	9.95	8.07	2306.6	.99	37133	17.0	0.0	0.0
68.0	12710.9	0.0	662.8	162.2	160.7	.246	.01	1.085	.0828	9.95	8.07	2307.1	.99	37132	17.0	0.0	0.0
69.0	12982.2	0.0	701.3	162.2	160.6	.246	.01	1.085	.0828	9.95	8.06	2305.7	.99	37131	17.0	0.0	0.0
70.0	13253.5	0.0	739.7	162.3	160.5	.246	.01	1.085	.0828	9.95	8.06	2305.6	.99	37130	17.0	0.0	0.0
RETARD THROTTLE SETTING TO 75.0 PERCENT IN 5.0 SEC.																	
71.0	13524.8	0.0	778.0	162.3	160.4	.246	.01	1.034	.0775	9.30	7.93	2267.9	.94	35830	16.2	0.0	0.0
BEGIN TURN TO HEADING 49.0 DEG.																	
72.0	13796.4	.0	814.8	162.3	160.3	.246	.01	1.007	.0748	8.95	7.47	2138.7	.91	33973	15.4	2.0	.0
73.0	14068.3	1.2	849.0	162.3	160.3	.246	.01	1.003	.0744	8.90	6.88	1968.6	.90	32116	14.8	7.0	.5
74.0	14340.8	5.9	880.3	162.3	160.2	.246	.00	1.015	.0755	9.05	6.21	1780.1	.91	30259	14.3	12.0	1.5
75.0	14612.9	16.7	908.3	162.3	160.1	.246	.01	1.030	.0771	9.25	5.50	1576.5	.92	28402	13.8	17.0	3.1
76.0	14885.2	36.2	932.8	162.3	160.1	.246	.10	1.093	.0837	10.05	4.81	1378.8	.98	27844	13.9	22.0	5.2
77.0	15156.6	67.6	954.6	162.4	160.1	.246	.11	1.172	.0925	11.05	4.32	1240.3	1.05	27843	14.4	27.0	8.1
78.0	15428.2	114.3	974.4	162.4	160.1	.246	.12	1.223	.0985	11.70	3.98	1142.7	1.10	27841	14.7	30.0	11.6
79.0	15692.3	178.2	992.7	162.5	160.2	.247	.29	1.223	.0985	11.70	3.67	1055.1	1.10	27839	14.4	30.0	15.3
80.0	15954.2	259.2	1009.3	162.8	160.4	.247	.47	1.219	.0981	11.65	3.35	965.3	1.10	27833	14.0	30.0	19.0
81.0	16210.9	357.1	1024.9	163.1	160.7	.247	.65	1.215	.0976	11.60	3.04	875.6	1.10	27826	13.6	30.0	22.7
82.0	16461.4	471.6	1038.7	163.5	161.1	.248	.83	1.207	.0966	11.50	2.72	786.3	1.10	27816	13.2	30.0	26.4
83.0	16704.0	602.3	1051.1	164.1	161.6	.249	1.03	1.199	.0957	11.40	2.40	696.5	1.10	27804	12.8	30.0	30.1
84.0	16948.4	748.9	1062.0	164.8	162.2	.250	1.22	1.191	.0948	11.30	2.08	606.1	1.10	27789	12.4	30.0	33.7
85.0	17167.4	910.5	1071.6	165.5	162.9	.251	1.51	1.183	.0938	11.20	1.91	559.7	1.10	27772	12.1	25.0	37.1
86.0	17386.5	1084.9	1081.0	166.3	163.7	.252	1.27	1.172	.0925	11.05	2.01	590.6	1.10	27754	12.1	20.0	39.8
87.0	17598.9	1269.3	1091.6	167.0	164.4	.253	1.10	1.164	.0916	10.95	2.32	685.4	1.10	27738	12.3	15.0	42.0
88.0	17805.9	1461.2	1104.2	167.6	164.9	.254	.84	1.156	.0906	10.85	2.80	828.7	1.10	27724	12.6	10.0	43.6
89.0	18009.2	1658.1	1119.4	168.0	165.3	.255	.53	1.148	.0898	10.75	3.38	1005.1	1.10	27714	13.1	5.0	44.5
90.0	18210.6	1857.4	1137.7	168.2	165.4	.255	.16	1.148	.0898	10.75	4.02	1195.9	1.10	27709	13.8	2.0	44.9
91.0	18411.0	2057.6	1159.2	168.2	165.4	.255	.01	1.101	.0845	10.15	4.59	1364.4	1.05	27708	13.7	0.0	45.0
92.0	18611.2	2257.9	1182.6	168.2	165.3	.255	.00	1.066	.0807	9.70	4.83	1434.1	1.02	27707	13.5	0.0	45.0
93.0	18811.3	2458.2	1206.8	168.2	165.3	.255	.01	1.050	.0791	9.50	4.91	1458.8	1.00	27707	13.4	0.0	45.0
94.0	19011.5	2658.4	1231.1	168.2	165.2	.255	.01	1.046	.0787	9.45	4.93	1466.8	1.00	27707	13.4	0.0	45.0
95.0	19211.6	2858.6	1255.6	168.2	165.2	.255	.01	1.046	.0787	9.45	4.94	1468.9	1.00	27706	13.4	0.0	45.0
96.0	19411.7	3058.9	1280.1	168.2	165.1	.256	.01	1.046	.0787	9.45	4.95	1470.1	1.00	27706	13.4	0.0	45.0

## TAKEOFF CONTINUED

TIME (SEC)	X DIST (FEET)	Y DIST (FEET)	ALT. (FEET)	TAS (KTS)	EAS (KTS)	MACH NO.	ACCEL (FPS2)	CL	CD	ALPHA (DEG)	GAMMA (DEG)	R/C (PPH)	LOAD FACT	THRUST (LBS)	PUS. ANG.	ROLL ANGLE	HEADING (DEG)
97,0	19611,8	3259,1	1304,6	168,3	165,1	,256	,01	1,046	,0787	9,45	4,95	1470,1	1,00	27705	13,4	0,0	45,0
98,0	19812,0	3459,4	1329,1	168,3	165,0	,256	,01	1,046	,0787	9,45	4,94	1468,9	1,00	27705	13,4	0,0	45,0
99,0	20012,1	3659,6	1353,6	168,3	165,0	,256	,00	1,050	,0791	9,50	4,94	1469,0	1,00	27704	13,4	0,0	45,0
100,0	20212,2	3859,9	1378,1	168,3	164,9	,256	,00	1,050	,0791	9,50	4,94	1469,0	1,00	27704	13,4	0,0	45,0
101,0	20412,4	4060,2	1402,6	168,3	164,8	,256	,00	1,050	,0791	9,50	4,94	1469,4	1,00	27704	13,4	0,0	45,0
102,0	20612,6	4260,4	1427,1	168,3	164,8	,256	,00	1,050	,0791	9,50	4,95	1470,6	1,00	27703	13,4	0,0	45,0
103,0	20812,7	4460,7	1451,6	168,3	164,7	,256	,00	1,050	,0791	9,50	4,95	1470,5	1,00	27703	13,4	0,0	45,0
104,0	21012,9	4661,0	1476,1	168,3	164,7	,256	,01	1,050	,0791	9,50	4,94	1469,2	1,00	27702	13,4	0,0	45,0
105,0	21213,0	4861,3	1500,5	168,3	164,6	,256	,01	1,050	,0791	9,50	4,94	1468,0	,99	27702	13,4	0,0	45,0
106,0	21413,2	5061,5	1525,0	168,3	164,6	,256	,01	1,050	,0791	9,50	4,94	1467,9	,99	27702	13,4	0,0	45,0
107,0	21613,4	5261,8	1549,5	168,3	164,5	,256	,00	1,054	,0795	9,55	4,94	1467,5	1,00	27701	13,5	0,0	45,0
108,0	21813,6	5462,1	1573,9	168,3	164,4	,256	,00	1,054	,0795	9,55	4,94	1468,5	1,00	27701	13,5	0,0	45,0
109,0	22013,8	5662,4	1598,4	168,3	164,4	,256	,01	1,054	,0795	9,55	4,94	1468,3	1,00	27700	13,5	0,0	45,0
110,0	22214,0	5862,7	1622,9	168,3	164,3	,256	,01	1,054	,0795	9,55	4,93	1466,9	1,00	27700	13,5	0,0	45,0
111,0	22414,2	6063,1	1647,3	168,3	164,3	,256	,00	1,058	,0799	9,60	4,93	1466,2	1,00	27700	13,5	0,0	45,0
112,0	22614,4	6263,4	1671,7	168,3	164,2	,256	,00	1,058	,0799	9,60	4,93	1465,9	1,00	27699	13,5	0,0	45,0
113,0	22814,6	6463,7	1696,2	168,3	164,2	,256	,00	1,058	,0799	9,60	4,93	1466,0	1,00	27699	13,5	0,0	45,0
114,0	23014,8	6664,0	1720,6	168,3	164,1	,256	,00	1,058	,0799	9,60	4,93	1466,9	1,00	27698	13,5	0,0	45,0
115,0	23215,0	6864,4	1745,1	168,3	164,1	,256	,01	1,058	,0799	9,60	4,93	1466,5	1,00	27698	13,5	0,0	45,0
ADVANCE THROTTLE SETTING TO 95,0 PERCENT IN 3,3 SEC.																	
116,0	23415,2	7064,7	1769,6	168,3	164,0	,256	,04	1,113	,0858	10,30	5,05	1501,3	1,05	29248	14,3	0,0	45,0
117,0	23615,4	7264,9	1795,8	168,3	164,0	,256	,01	1,156	,0904	10,85	5,58	1658,2	1,09	31463	15,4	0,0	45,0
118,0	23815,3	7465,0	1825,1	168,4	163,9	,256	,04	1,160	,0911	10,90	6,24	1853,2	1,10	33678	16,1	0,0	45,0
119,0	24015,0	7664,8	1857,6	168,4	163,8	,256	,01	1,136	,0884	10,60	6,90	2049,9	1,08	35081	16,5	0,0	45,0
120,0	24214,5	7864,0	1892,8	168,4	163,8	,256	,01	1,081	,0824	9,90	7,24	2191,9	1,02	35080	16,1	0,0	45,0
121,0	24413,9	8063,9	1929,0	168,4	163,7	,256	,01	1,062	,0803	9,65	7,37	2189,9	1,00	35079	16,0	0,0	45,0
122,0	24613,3	8263,4	1969,7	168,4	163,6	,256	,01	1,054	,0795	9,55	7,42	2203,4	,99	35078	16,0	0,0	45,0
123,0	24812,6	8462,9	2002,4	168,4	163,5	,256	,01	1,054	,0795	9,55	7,43	2207,0	,99	35078	16,0	0,0	45,0
ACCELERATE TO CLIMB SPEED OF 250,0																	
124,0	25012,0	8662,4	2039,0	168,5	163,5	,256	,20	1,015	,0755	9,05	7,32	2173,8	,96	35076	15,4	0,0	45,0
125,0	25211,7	8862,2	2074,5	168,7	163,6	,257	,51	,975	,0717	8,55	6,96	2070,1	,92	35070	14,5	0,0	45,0
126,0	25411,9	9062,5	2107,7	169,1	163,9	,257	,95	,936	,0681	8,05	6,36	1899,4	,88	35058	13,4	0,0	45,0
127,0	25613,1	9263,8	2137,4	169,8	164,5	,259	1,49	,897	,0646	7,55	5,55	1665,5	,85	35038	12,1	0,0	45,0
128,0	25815,6	9466,4	2162,9	170,9	165,5	,260	2,07	,873	,0626	7,25	4,58	1384,1	,84	35008	10,8	0,0	45,0
129,0	26019,9	9670,8	2183,5	172,3	166,8	,262	2,66	,854	,0610	7,00	3,56	1084,0	,83	34968	9,6	0,0	45,0
130,0	26226,2	9877,3	2199,0	174,0	168,5	,265	3,26	,834	,0594	6,75	2,50	770,7	,83	34919	8,3	0,0	45,0
131,0	26435,1	10086,3	2209,3	176,0	170,4	,268	3,24	,976	,0718	8,56	1,70	530,1	1,00	34860	9,3	0,0	45,0
132,0	26646,3	10297,6	2218,1	178,0	172,2	,271	3,25	,956	,0700	8,31	1,68	530,0	1,00	34805	9,0	0,0	45,0
133,0	26859,9	10511,3	2227,0	179,9	174,1	,274	3,26	,937	,0682	8,07	1,67	530,1	1,00	34750	8,7	0,0	45,0
134,0	27075,7	10727,3	2235,8	181,8	175,9	,277	3,28	,918	,0665	7,82	1,65	530,0	1,00	34694	8,5	0,0	45,0
135,0	27293,9	10949,6	2244,6	183,8	177,8	,280	3,29	,900	,0649	7,59	1,63	530,0	1,00	34638	8,2	0,0	45,0
BEGIN TURN TO HEADING -15,0 DEG.																	
136,0	27514,4	11166,2	2253,5	185,7	179,7	,283	3,29	,883	,0634	7,37	1,61	530,0	1,00	34582	8,0	-1,5	45,0
137,0	27737,9	11388,4	2262,3	187,7	181,5	,286	3,29	,871	,0624	7,22	1,60	529,8	1,00	34526	7,8	-6,5	44,6
138,0	27966,3	11610,3	2271,1	189,6	183,4	,289	3,26	,866	,0620	7,15	1,58	529,8	1,02	34470	7,7	-11,5	43,7
139,0	28201,6	11829,7	2280,0	191,5	185,2	,292	3,20	,867	,0621	7,18	1,56	529,8	1,04	34415	7,7	-16,5	42,2
140,0	28445,7	12044,2	2288,8	193,4	187,0	,294	3,12	,877	,0630	7,30	1,55	529,8	1,07	34361	7,9	-21,5	40,3
141,0	28700,3	12251,1	2297,6	195,2	188,7	,297	3,06	,884	,0635	7,39	1,52	525,5	1,10	34309	7,9	-26,5	37,8
142,0	28966,7	12447,6	2306,1	197,1	190,5	,300	3,12	,865	,0619	7,15	1,43	499,7	1,09	34256	7,6	-24,1	35,1
143,0	29244,4	12633,8	2314,4	198,9	192,2	,303	3,12	,852	,0609	6,98	1,42	499,8	1,10	34203	7,4	-24,4	32,6
144,0	29532,5	12809,1	2322,7	200,7	194,0	,306	3,12	,837	,0596	6,78	1,41	500,2	1,10	34150	7,2	-24,7	30,1



TAKEOFF CONTINUED

TIME (SEC)	X DIST (FEET)	Y DIST (FEET)	ALT. (FEET)	TAB (KTS)	EAS (KTS)	MACH NO.	ACCEL (FPS2)	CL	CD	ALPHA (DEG)	GAMMA (DEG)	R/C (PPH)	LOAD FACT	THRUST (LBS)	FUS. ANG.	ROLL ANGLE	HEADING (DEG)
145.0	29830.8	12973.4	2331.1	202.6	195.7	.309	3.13	.822	.0585	6.60	1.39	499.6	1.10	34097	7.0	-24.3	27.6
146.0	30138.6	13126.1	2339.4	204.4	197.5	.311	3.14	.804	.0571	6.37	1.38	500.3	1.09	34044	6.8	-24.1	25.2
147.0	30455.5	13266.8	2347.7	206.3	199.3	.314	3.13	.795	.0564	6.25	1.37	500.3	1.10	33990	6.6	-24.7	22.7
FLAPS RETRACTED TO 2.0 DEG. IN 1.0 SEC.																	
148.0	30780.9	13395.2	2356.1	208.2	201.1	.317	3.21	.778	.0532	6.75	1.36	500.0	1.10	33937	7.1	-24.2	20.3
149.0	31114.5	13511.0	2364.4	210.1	202.9	.320	3.29	.764	.0503	7.28	1.35	500.3	1.10	33881	7.6	-24.7	18.0
150.0	31455.7	13613.8	2372.7	212.1	204.8	.323	3.30	.751	.0492	7.11	1.33	500.3	1.10	33825	7.4	-24.8	15.6
151.0	31804.1	13703.4	2381.1	214.0	206.6	.326	3.31	.735	.0480	6.91	1.32	500.4	1.09	33769	7.2	-25.0	13.3
152.0	32159.0	13779.5	2389.4	216.0	208.5	.329	3.31	.725	.0472	6.78	1.31	500.1	1.10	33712	7.1	-24.7	10.9
FLAPS RETRACTED TO 0.0 DEG. IN .7 SEC.																	
153.0	32519.9	13841.8	2397.8	217.9	210.4	.332	3.34	.709	.0457	6.72	1.30	499.3	1.09	33656	7.0	-23.9	8.6
154.0	32886.4	13890.2	2406.1	220.0	212.3	.335	3.44	.696	.0425	7.37	1.29	500.1	1.10	33598	7.7	-23.2	6.4
155.0	33258.0	13924.4	2414.4	222.0	214.2	.338	3.45	.685	.0416	7.22	1.27	500.3	1.10	33539	7.5	-24.6	4.1
156.0	33634.0	13944.3	2422.8	224.0	216.2	.341	3.46	.672	.0407	7.06	1.26	500.3	1.10	33480	7.3	-24.5	1.9
157.0	34014.0	13949.8	2431.1	226.1	218.1	.344	3.46	.660	.0398	6.90	1.25	499.9	1.09	33422	7.1	-24.0	-.3
158.0	34397.3	13940.7	2439.4	228.1	220.1	.348	3.46	.649	.0390	6.77	1.24	500.4	1.10	33363	7.0	-24.5	-2.4
159.0	34783.5	13916.8	2447.8	230.2	222.0	.351	3.46	.639	.0383	6.63	1.23	499.8	1.10	33304	6.9	-24.3	-4.6
160.0	35172.0	13878.1	2456.1	232.2	224.0	.354	3.46	.628	.0375	6.50	1.22	500.3	1.10	33245	6.7	-24.6	-6.8
161.0	35562.2	13824.5	2464.4	234.3	225.9	.357	3.48	.615	.0366	6.32	1.21	500.2	1.09	33185	6.5	-24.0	-8.9
162.0	35953.6	13756.1	2472.8	236.4	227.9	.360	3.52	.591	.0351	6.03	1.20	500.4	1.07	33126	6.2	-21.0	-10.9
163.0	36346.1	13674.8	2481.1	238.5	229.9	.363	3.58	.565	.0334	5.69	1.19	500.4	1.04	33066	5.9	-16.0	-12.4
164.0	36740.2	13583.7	2489.5	240.6	231.9	.367	3.62	.544	.0321	5.42	1.18	500.5	1.02	33004	5.6	-11.0	-13.5
165.0	37136.3	13485.6	2497.8	242.7	234.0	.370	3.64	.528	.0312	5.22	1.17	500.4	1.00	32942	5.4	-6.0	-14.2
166.0	37535.1	13383.4	2506.1	244.9	236.0	.373	3.65	.516	.0305	5.07	1.16	500.7	1.00	32880	5.2	-2.0	-14.5
167.0	37937.1	13278.9	2514.5	247.1	238.1	.376	3.64	.507	.0301	4.96	1.15	500.7	1.00	32818	5.1	-2.0	-14.6
168.0	38342.4	13172.4	2522.8	249.2	240.1	.380	3.63	.499	.0296	4.86	1.14	500.5	1.00	32756	5.0	-2.0	-14.8
EXECUTE PULLUP AT DADT = .13																	
169.0	38750.8	13063.9	2531.4	251.3	242.1	.383	3.51	.509	.0302	4.98	1.20	534.9	1.03	32695	5.2	-2.0	-15.0
170.0	39162.4	12953.6	2541.1	253.4	244.0	.386	3.31	.519	.0307	5.11	1.43	640.7	1.07	32636	5.5	0.0	-15.0
171.0	39577.1	12842.4	2553.1	255.2	245.8	.389	3.02	.529	.0313	5.23	1.81	818.0	1.11	32582	6.0	0.0	-15.0
172.0	39994.6	12730.4	2566.7	256.9	247.4	.392	2.64	.539	.0318	5.36	2.34	1064.8	1.14	32533	6.7	0.0	-15.0
173.0	40414.5	12617.8	2589.0	258.3	248.7	.394	2.19	.548	.0324	5.48	3.02	1378.5	1.17	32490	7.5	0.0	-15.0
174.0	40836.1	12504.8	2615.0	259.5	249.7	.396	1.69	.554	.0328	5.56	3.82	1752.6	1.20	32456	8.4	0.0	-15.0
175.0	41259.0	12391.4	2647.5	260.4	250.4	.397	1.21	.552	.0327	5.53	4.66	2143.4	1.20	32429	9.2	0.0	-15.0
176.0	41682.6	12277.8	2686.4	260.9	250.8	.398	.74	.550	.0325	5.51	5.50	2533.4	1.20	32411	10.0	0.0	-15.0
177.0	42106.3	12164.2	2731.9	261.2	250.9	.399	.28	.548	.0324	5.48	6.34	2923.5	1.20	32400	10.8	0.0	-15.0
178.0	42529.6	12050.7	2783.8	261.3	250.8	.399	.00	.511	.0303	5.01	7.11	3276.5	1.11	32397	11.1	0.0	-15.0
179.0	42952.4	11937.3	2839.7	261.3	250.6	.399	.01	.470	.0281	4.48	7.38	3403.1	1.02	32395	10.9	0.0	-15.0
180.0	43375.1	11824.0	2896.7	261.3	250.4	.399	.01	.460	.0276	4.36	7.45	3432.9	1.00	32394	10.8	0.0	-15.0
181.0	43797.7	11710.6	2954.0	261.3	250.2	.399	.01	.458	.0275	4.33	7.47	3442.1	.99	32392	10.8	0.0	-15.0
181.7	44093.6	11631.3	2994.2	261.3	250.0	.399	.01	.457	.0274	4.32	7.47	3443.8	.99	32391	10.8	0.0	-15.0

END OF TAKEOFF

# APPENDIX C - PROGRAM LISTING

TAKOFF

C SUBROUTINE TAKOFF(INPC,IDCN,WGROSS,SWING,XENG,VR,VEND)  
C  
C SUBROUTINE TAKOFF COMPUTES THE TAKEOFF MANEUVER OF A GIVEN AIRCRAFT,  
C INCLUDING GROUND ROLL AND CLIMBOUT,  
C  
C PROVISIONS ARE MADE FOR CHANGES IN FLAP,VECTORED THRUST ANGLE AND POWER  
C SETTINGS AS FUNCTIONS OF SPEED AND ALTITUDE,  
C  
C HEADING ANGLES ARE DETERMINED BY ALTITUDE AND GROUND DISTANCES.  
C  
C FOLLOWING SOME COMMENT CARDS WILL BE TWO NUMBERS IN PARENTHESIS WHICH  
C WILL GIVE THE APPROXIMATE STATEMENT-NUMBER RANGE OF THE FUNCTION  
C DESCRIBED IN THAT COMMENT.

EXTERNAL DERIV1  
EXTERNAL DERIV2  
REAL MU,METRIC  
COMMON /UNIV/ NPC ,NSC ,IDC ,H ,ST ,R ,W ,  
1WF ,EM ,VMO ,EMMO ,ALPHLO,CLALPH,SW ,AR ,B ,  
2EYEW ,ENP ,TA ,WG ,WGS ,KWRITE,OLMC4  
3,KSIZE  
COMMON /AERO/ VEL,OS,HABS,THRUST,TVECT, ANGLE,DELFD,DELSPL,ALPHA,  
9CX,CY,CL,CD,RHO,GRCD,IFAST  
COMMON /ROLL/ PHI,ROCMIN  
COMMON /EXCHNG/ SROLL,S3S,V3S,T5J  
COMMON /XROLL/T(30),NEQ,MU,NREV  
COMMON /XFLATE/ S(5),RDC,THEMAX,THETAF,XLF,XLFMAX,K  
COMMON /UNIT/IUNIT,G  
DIMENSION ANS(8)  
DIMENSION XDELFD(5),XHFLAP(5),XVFLAP(5)  
DIMENSION XHPWR(5),XVPWR(5),XPPOWER(5)  
DIMENSION XNU(5),XHVECT(5),XVVECT(5)  
DIMENSION XPRANGE(5),XHHEAD(5),XHEAD(5)  
YYY(XXX,Y1,Y2,X1,X2) = Y1 + (Y2-Y1)\*(XXX-X1)/(X2-X1)  
DATA XDELFD/15.0,5.0,2.0,0.0,0.0/, XHFLAP/0.0,250.0,0.0,0.0,0.0/,  
9XVFLAP/0.0,0.0,200.0,210.0,0.0/, XPPOWER/1.0,1.0,1.0,1.0,1.0/, XHPWR/  
90.0,0.0,0.0,0.0,0.0/, XVPWR/0.0,999.999,999.999,999.999,/  
90.0,0.0,0.0,0.0,0.0/, XHVECT/0.0,0.0,0.0,0.0,0.0/, XVVECT/0.0,999.999,/  
9999.999,/  
DATA XPRANGE/5\* 100.00/, XHHEAD/5\*99999.9/, XHEAD/5\*0.0/  
DATA CDGEAR,DFLPDT,DTABS,DTGR,OTPDWN,DTPUP,DIVECT,EYEWNG,HAPT,  
9HGR,HMAN,IDUT,UM,PMARG,RTCL,THTFLY,THTSCP/0.0,3.0,0.0,5.0,5.0,6.0,  
910.0,1.0,0.0,25.0,1000.0,0.02,0.04,750.0,15.0,10.0/  
DATA ROLLMX,RDLRAT,ROCMIN,HDT/15.0,5.0,250.0,35.0/  
DATA METRIC/1MM/  
NAMLIST/NAM1/CDGEAR,DADT,DFLPDT,DTABS,DTGR,OTPDWN,DTPUP,DIVECT,  
9EYEWNG,HAPT,HGR,HMAN,HMAX,IDUT,UM,NPAGE,PMARG,RTCL,THTFLY,  
9THTSCP,XLFMAX,ROLLMX,RDLRAT,ROCMIN,HDT  
NAMLIST/NAM2/XDELFD,XHFLAP,XVFLAP,XPPOWER,XHPWR,XVPWR,XNU,XHVECT,  
9XVVECT  
NAMLIST/NAM3/XPRANGE,XHHEAD,XHEAD  
GO TO(5,6,5),INPC  
36 5 NPAGE = 33  
37 DADT = 1.0  
40 HMAX = 5000.  
42 XLFMAX = 1.10

# TAKOFF

```

C
C   SET UP FOR UNITS CONVERSION
C
43   VELFTR = 0.592087
45   LENGFTR = 6076.
46   DSTOP = 60760.
50   CDGFTR = 1.00
51   G = 32.2
53   IUNIT = 1
54   READ(5,500)UNITS
500  FORMAT(A1)
66   IF(UNITS .NE. 'METRIC')GO TO 501
70   VELFTR = 1.00
71   LENGFTR = 1000.
73   DSTOP = 18530.
74   CDGFTR = 0.02798
76   G = 9.8
77   IUNIT = 2
101  501 CONTINUE

C
C   CALL INPUT TO TAKOFF THRU NAMELIST /NAM1/, /NAM2/, AND /NAM3/
C
101  READ(5,NAM1)
104  READ(5,NAM2)
112  READ(5,NAM3)
120  IF(INPC .EQ. 1)RETURN
126  6 ENP = XENG
127  SW = SWING
130  K = WKDSS
131  EYEW = EYFANG
132  MU = UM
134  S(7) = HAPT
136  DO 7 I = 2,4
137  IF(XHPWR(I) .NE. 0.0)XVPWR(I) = 0.0
143  IF(XHVECT(I) .NE. 0.0)XVVECT(I) = 0.0
147  7 CONTINUE

C
C   SET UP LOGIC CONTROL VARIABLES
C
151  NEO = 2
152  IPAGE = 0
153  KENG = 0
153  JJ1 = 1
154  JJ2 = 1
155  IUP = 1
156  IDOWN = 1
156  IFLY = 1
157  IFIAP = 2
160  MFLAP = 1
161  JROUTE = 1
161  IPWR = 1
162  MPWR = 2
163  MVECT = 1
163  IVECT = 2
164  I35 = 1
165  IG = 0

```

# YAKOFF

```

166      IROLL = 1
166      MROLL = 0
167      IHEAD = 1
170      PHIMAX = ROLLMX/57.3
172      TINT = 10.0

C
C      FIND GEAR DRAG IF DEFAULT OF CDGEAR=0.0 USED
C
174      IF(CDGEAR.EQ. 0.0)CDGEAR = (0.0032/SW)***0.80
204      CDGEAR = CDGFTR*CDGEAR
206      GRCD = CDGEAR
206      IF(IDCN.NE. 9)GO TO 299
210      TEMP = 59.0 + DTABS
212      WG = WGROSS
213      WOS = W/SW

C
C      FIND STATIC THRUST/WEIGHT
C
215      CALL ENGINF(0.0,0.0,0.0,0.0,1.0,WF,KENG)
221      TOW = ENP * THRUST / W

C
C      WRITE OUT PROGRAM INPUTS
C
224      WRITE(6,201)HAPT,TEMP
201      FORMAT(/, 36H ** INPUTS TO TAKE OFF - ALTITUDE = ,F6.1,2X,14HTEMP
          9ERATURE = ,F5.1,7H DEG. )
243      WRITE(6,202)WG,SW,THRUST
202      FORMAT(/,6X,19H/C CHARACTERISTICS,/,9X,17HMGROSS RAMP WT. = ,F8.0,
          93X,12HWINW AREA = ,F6.0,3X,26HSTATIC SEA LEVEL THRUST = ,F6.0)
260      WRITE(6,203)WOS,TOW
203      FORMAT(9X,15HWINW LOADING = ,F5.1,3X,16HTHRUST/WEIGHT = ,F4.3)
273      WRITE(6,204)ENP,CDGEAR,EYEW,THTSCP
204      FORMAT(/,6X, 15H/C PARAMETERS,/,9X,14HNO. ENGINES = ,F3.1,3X, 9HC
          9DGEAR = ,F6.4,3X,9HEYEWNG = ,F4.1,3X,20HTAIL SCRAPE ANGLE = ,F4.1)
312      WRITE(6,205)XLFMAX,HGR,THTFLY,HMAN,RTCL
205      FORMAT(/,6X,30HFLIGHT PATH CONTROL PARAMETERS,/,9X,18HMAX LOAD FAC
          9TDR = ,F4.2,3X,23HGEAR RETRACTION ALT. = ,F5.1,3X,18HMAX FLOOR ANG
          9LE = ,F4.1,/,9X,16HMANEUVER ALT. = ,F5.0,5X,27HACCELERATE RATE OF
          9CLIMB = ,F5.0)
333      WRITE(6,206)DADT,DPLPDT,DTGR,DTPDWN,DTPUP,DIVECT
206      FORMAT(/,6X,25HPARAMETER VARIATION RATES,/,9X, 7HDADT = ,F4.1,3X
          9,9HDPLPDT = ,F4.1,3X,7HDTGR = ,F4.1,3X,9HDTPDWN = ,F4.1,/,9X,8HDTD
          9UP = ,F4.1,3X,9HDTVECT = ,F4.1)
356      WRITE(6,207)
207      FORMAT(/,6X,42HPOWER, VECTORED THRUST, AND FLAP SCHEDULES)
365      WRITE(6,208)(XPOWER(I),I = 1,5)
208      FORMAT(/,9X,22HTHROTTLE/POWER SETTING,/,12X,8HPWRSET ,5F9.2)
376      WRITE(6,209)(XVPWR(I),I = 1,5)
209      FORMAT(12X,8HSPEED ,5F9.1)
407      WRITE(6,210)(XMPWR(I),I = 1,5)
210      FORMAT(12X,8HALTITUDE,5F9.0)
420      WRITE(6,211)(XNU(I),I = 1,5)
211      FORMAT(/,9X,21HVECTORED THRUST ANGLE,/,12X,8HANGLE ,5F9.1)
431      WRITE(6,209)(XVVECT(I),I = 1,5)
436      WRITE(6,210)(XMVECT(I),I = 1,5)
447      WRITE(6,212)(XDELFD(I),I = 1,5)

```

# TAKOFF

```

212 FORMAT(/,9X,21HFLAP DEFLECTION ANGLE,/,12X,8HDEFLD ,SF9,1)
464 WRITE(6,209)(XVFLAP(I),I = 1,5)
471 WRITE(6,210)(XMFLAP(I),I = 1,5)
502 WRITE(6,213)
213 FORMAT(/,9X,76HALL SPEEDS ARE INDICATED AIR SPEEDS AND ALL ALTITUDES ARE ABSOLUTE ALTITUDES)
515 WRITE(6,214)
214 FORMAT(/,6X,18HDEPARTURE HEADINGS,/)
524 WRITE(6,215)(XRANGE(I),I=1,5)
215 FORMAT(12X,8HRRANGE ,SF10,1)
535 WRITE(6,216)(XMHEAD(I),I = 1,5)
216 FORMAT(12X,8HALTITUDE ,SF10,1)
546 WRITE(6,217)(XHEAD(I),I=1,5)
217 FORMAT(12X,8HHEADING ,SF10,1)
557 299 CONTINUE
557 IF(IDCN ,EQ. 9)
+WRITE(6,999)HAPT
999 FORMAT(1H1,/,21H TAKEOFF (ELEVATION =,F6,0,4H FT),/)
572 IF(IDCN ,EQ. 9 .AND. IUNIT ,EQ. 1)WRITE(6,1000)
610 IF(IDCN ,EQ. 9 .AND. IUNIT ,EQ. 2)WRITE(6,2000)

C
C SET FLAPS, VECTORED THRUST ANGLE AND POWER SETTING FOR GROUND RUN
C
626 PWRSET = XPOWER(1)
627 ANGLE = XNU(1)
631 DFLFD = XDEFLD(1)
632 THFMAX = THTSCP
634 HABS = 0.0
634 VFL = 0.
635 ZERO = 0.
636 Z = 0.0
636 THFTAF = 0.
637 QS = 0.1
640 S(7) = HAPT
642 EM = 0.

C GROUND ROLL INTEGRATION VARIABLES
C T(1) = NUMBER OF EQUATIONS
C T(2) = TIME (SEC.)
C T(3) = TIME INTERVAL, STEP SIZE (SEC.)
C T(4) = VELOCITY (FT./SEC.) OR (M/SEC.)
C T(5) = DISTANCE (FT.) OR (M)
C T(6) = ACCELERATION (FT./SEC.**2) OR (M/SEC.**2)
C
642 T(1) = 2
644 T(2) = 0.0
645 T(3) = 0.1
646 T(4) = 0.
646 T(5) = 0.

C
C OBTAIN ATMOSPHERIC VARIABLES
C
650 CALL ATMOS(HAPT,DTABS,ANS)
652 SA = ANS(4)
653 RHO = ANS(3)
655 NCOUNT = 0

```

36

```

655 ALPHA = EYEW
C
C FIND INITIAL CONDITIONS OF THRUST AND FORCE COEFF. FOR GROUND ROLL
C
657 CALL ENGINE(S(7),DTABS,EM,PWRSET,Wf,KENG)
665 IFAST = 0
666 CALL ARDDYN
667 CALL INTS(T,2,2,1.,1.,1.,1.,1.,1., DERIV1)
701 TA = THRUST * ENP
703 IF(IDCN .EQ. 9)
+WRITE(6,1002)T(2),T(5),ZERO,ZERO,ZERO,ZERO,ZERO,ZERO,T(6),CL,CD,ALPHA,
9ZERO,ZERO,ZERO,TA,ZERO,ZERO,ZERO
C
C MAIN GROUND ROLL INTEGRATION LOOP (1-120)
C
767 1 NCOUNT = NCOUNT + 1
771 ALPHAJ = ALPHA
772 THETAJ = THETA
C
C CHECK IF LIFT = WEIGHT = LIFTOFF
C
773 IF(QS*CY .GE. W)GO TO 120
C
C CHECK SPEED FOR VR
C
777 106 IF(T(4)* VELFTR*SQRT(ANS(7)) .GE. VR)GO TO 101
1011 GO TO 110
C
C BEGIN ROTATION
C
1012 101 IF(JJ2 .EQ. 2)GO TO 103
1014 JJ2 = 2
1015 VKTS = T(4) * VELFTR
1017 EAS = VKTS*SQRT(ANS(7))
1023 IF(IDCN .EQ. 9)*WRITE(6,1009)T(2),VKTS,EAS
1009 FORMAT(1X,18HROTATION (TIME = ,F6,1,3X,10HAND TAS = ,F7,1,2X,
9AEAS = ,F7,1,14))
C
C INCREASE ALPHA AT RATE DADT AND RESTRICT TO VALUE .LE. TAIL SCRAPE
C
C ANGLE (103-102)
C
1047 103 ALPHA = ALPHA + T(3)*DADT
1052 IF((ALPHA - EYEW) .LE. THEMAX)GO TO 102
1055 ALPHA = THEMAX + FVF%
1056 GO TO 110
1056 102 THETA = ALPHA - EYEW
1060 110 EM = T(4)/SA
1062 QS = 0.5*RHO*SW*T(4)*T(4)
1066 CALL ENGINE(S(7),DTABS,EM,PWRSET,Wf,KENG)
1073 IFAST = 0
1074 VEL = T(4)
1075 TA = ENP*THRUST
1080 CALL INTM(T,2,2,1.,1.,1.,1.,1.,1., DERIV1)
C
C MAKE INTEGRATION STEP

```

# TAKOFF

```

C
1111 W = W - W*ENP*T(3)/3600.
1115 IF(T(2) .LE. 90)GO TO 113
1124 WRITE(6,1057)
1057 FORMAT(/,35H TIME LIMIT FOR GROUND RUN EXCEEDED)
1133 RETURN
1135 113 CONTINUE

C
C C COMPUTE ALPHA DOT AND THETA DOT
C
1133 XDAOT = (ALPHA - ALPHAJ)/T(3)
1136 OTHDOT = (THETAJ - THETAJ)/T(3)
1140 IF(NCOUNT .LT. 10)GO TO 1
1143 NCOUNT = 0
1143 VKTS = T(4) * VELFTR
1146 EAS = VKTS * SQRT(ANS(7))
1152 IF(IDCN .NE. 9)GO TO 1
1160 IF(IDCN .EQ. 9)
+WRITE(6,1002)T(2),T(5),Z,ZERO,VKTS,EAS,EM,T(6),CL,CD,ALPHA,ZERO,
+ZERO,ZERO,TA,THETAJ,ZERO,ZERO
1237 IPAGE = IPAGE +1
1241 IF(IPAGE .LT. NPAGE)GO TO 1
1243 IPAGE = 0
1243 IF(IDCN .EQ. 9)
+WRITE(6,998)
998 FORMAT(1H1,/,19H TAKEOFF CONTINUED ,/)
1254 IF(IDCN .EQ. 9 .AND. IUNIT .EQ. 1)WRITE(6,1000)
1272 IF(IDCN .EQ. 9 .AND. IUNIT .EQ. 2)WRITE(6,2000)
1310 GO TO 1
1311 120 VKTO = T(4) * VELFTR
1313 EASTO = VKTO * SQRT(ANS(7))
1317 SROLL = T(5)
1321 IF(IOUT .EQ. 1)ENP = ENPOUT
1330 IF(IDCN .EQ. 9)WRITE(6,1010)T(2),T(5),VKTO,EASTO
1010 FORMAT(1X,17H1LIFTOFF (TIME = ,F6.1,2X,7HDIST = ,F8.1,2X
+9,6HTAS = ,F7.1,1X,6HEAS = ,F7.1,1H)
1000 FORMAT(131H TIME X DIST Y DIST ALT TAS EAS MACH A
+9CCCL CL CD ALPHA GAMMA R/C LOAD THRUST FUS. RO
+9LL HEADNG,,131H (SEC) (FEET) (FEET) (FEET) (KTS) (KTS)
+9NO, (FPS2) (DEG) (DEG) (FPM) FACT (LBS) ANG
+9. ANGLE (DEG),/)
2000 FORMAT(131H TIME X DIST Y DIST ALT TAS EAS MACH A
+9CCCL CL CD ALPHA GAMMA R/C LOAD THRUST FUS. RO
+9LL HEADNG,,131H (SEC) (MTRS) (MTRS) (MTRS) (M/S) (M/S)
+9NO, (MPS2) (DEG) (DEG) (M/M) FACT (NTS) ANG
+9. ANGLE (DEG),/)
1002 FORMAT(1X,F5.1,F9.1,F9.1,F9.1,F7.1,F6.1,F6.3,F7.2,F7.3,F7.4,2F7.2,
+9F8.1,F6.2,F9.0,F6.1,F7.1,F8.1)

C
C C END OF GROUND ROLL - BEGIN AIRBORNE PORTION OF TAKEOFF
C
1353 VMARG = PMARG*VFEND
1355 THEMAX = THFLY

C
C C FLAP, ANGLE AND POWER SCHEDULES SET UP FOR AIRBORNE PORTION
C

```

# TAKOFF

```

1356 HFLAP = XMFLAP(2)
1360 VFLAP = XVFLAP(2)
1361 HPOWER = XHPWR(2)
1363 VPOWER = XVPWR(2)
1364 HVECT = XHVECT(2)
1366 VVECT = XVVECT(2)
1367 RANGE = XRANGE(1)*RNGFTR
1371 HMEAD = XHMEAD(1)
1373 PHI = 0.0
1373 XLF = 1.0

```

```

C
C AIRBORNE INTERGRATION VARIABLES
C S(1) = NUMBER OF EQUATIONS
C S(2) = TIME (SEC.)
C S(3) = TIME INTERVAL, STEP SIZE (SEC.)
C S(4) = VELOCITY ALONG FLIGHT PATH (FT./SEC.) OR (M/SEC)
C S(5) = FLIGHT PATH ANGLE (RAD.)
C S(6) = HEADING ANGLE (RAD.)
C S(7) = ALTITUDE (FT.) OR (M)
C S(8) = X-DISTANCE (FT.) OR (M)
C S(9) = Y-DISTANCE (FT.) OR (M)
C S(10) = ACCELERATION ALONG FLIGHT PATH (FT./SEC.**2) OR (M/SEC.**2)
C S(11) = TIME RATE OF CHANGE OF FLIGHT PATH ANGLE (RAD./SEC.)
C S(12) = TIME RATE OF CHANGE OF HEADING ANGLE (RAD/SEC)
C S(13) = RATE OF CLIMB (FT./SEC) OR (M/SEC)
C S(14) = SPEED ALONG X-DIRECTION
C S(15) = SPEED ALONG Y-DIRECTION
C

```

```

1375 S(1) = 6
1376 S(2) = T(2)
1400 S(3) = 0.1
1401 S(4) = T(4)
1403 S(5) = 0.
1403 S(6) = 0.0
1404 S(8) = T(5)
1406 S(9) = 0.0
1407 CALL INTS(S,6,2,1.,1.,1.,1.,1.,1., DERIV2)
1420 GO TO 500

```

```

C
C MAIN AIRBORNE INTEGRATION LOOP (2=8)
C

```

```

1424 2 NCOUNT = NCOUNT + 1
1426 ALPHAJ = ALPHA
1427 THETAJ = THETA
1430 IF((S(7) - HAPT) .GE. HMAX) RETURN

```

```

C
C CHECK PROGRAM PROTECTION LIMITS
C

```

```

1435 IF(AHS(T(5)) .GT. DSTOP) GO TO 9
1442 IF(AHS(S(9)) .GT. DSTOP) GO TO 9
1446 IF(S(7) .LT. -0.1) GO TO 9
1450 IF(S(2) .GT. 300.) GO TO 9

```

```

C
C OBTAIN ATMOSPHERIC VARIABLES
C

```

```

1454 300 CALL ATMOS(S(7),DTABS,ANS)

```



## TAKOFF

```

1460      SA = ANS(4)
1461      RHO = ANS(3)
1463      EM = S(4)/SA
1464      HABS = S(7) - HAPT
C
C      CALL ENGINE WITH PWRSET (KENG=0)
C
1467      CALL ENGINE(S(7),DTABS,EM,PWRSET,WF,KENG)
1474      W = W - WFAENP*S(3)/3600,
C
C      BEGIN AERODYNAMIC CONTROL
C
1500      K = 1
C
C      CHECK FOR START OF PULLUP MANEUVER
C
1501      IF ((VEND = S(4)*SQRT(ANS(7))* VELFTR).LT. VMARG)GO TO 27
1521      IF((S(7) - HAPT).LT. HMAN)GO TO 4
1525      IF(IFLY.EQ. 2)GO TO 28
1527      IFLY = 2
1527      IF(RTCL.GT. ROC)GO TO 9
1533      IF(IDCN.EQ. 9)
C
C      ACCELERATION TO VEND AT CONSTANT RATE OF CLIMB (28-27)
C
      *WRITE(6,1040)VEND
1040 FORMAT(1X,29HACCELERATE TO CLIMB SPEED OF ,F6.1)
1546      28 IF(S(4)*SIN(S(5))*60.0.LE. RTCL + 10,)GO TO 29
C
C      REDUCE ALPHA TO START ACCELERATION PHASE
C
1562      ALPHA = ALPHA - DADT*S(3)*0.5
1565      IF(XLF.LT. 0.85)ALPHA = ALPHA + DADT*S(3)*0.25
1573      GO TO 26
1574      29 K = 9
1575      ROC = RTCL
1577      GO TO 26
1577      27 IF(JROUTE.EQ. 2)GO TO 41
1601      XLFMAX = 1.2
C
C      PULLUP MANEUVER - FIND REQUIRED DADT (27-44)
C
1603      CALL PULLUP(DADT,KODE,PWRSET,KENG,VEND,HAPT,DTABS)
1612      IF(KODE.EQ. 9)GO TO 9
1620      IF(IDCN.EQ. 9)WRITE(6,1056)DADT
1056 FORMAT(26H EXECUTE PULLUP AT DADT = ,F4.2)
1632      JROUTE = 2
1633      GO TO 4
1634      41 GO TO(42,43,44),KODE
1643      42 IF(S(4)*SQRT(ANS(7))* VELFTR.LT. VEND.AND. S(10).LT. .02)GO TO
      98
1664      GO TO 4
1664      43 IF(S(4)*SQRT(ANS(7))* VELFTR.GE. VEND)GO TO 8
1677      GO TO 4
1700      44 IF(S(10).LT. 0.02)GO TO 8

```

# TAKOFF

```

C INCREASE ANGLE OF ATTACK EACH TIME BEFORE INTEGRATION STEP TAKEN
C (EXCEPT FOR CONSTANT RATE OF CLIMB PORTION), FOR LOAD FACTOR
C .LT. 1.0, ADDITIONAL INCREASE IN ALPHA. IF THE INCREASE IN ALPHA
C RESULTS IN ANY VIOLATION OF FLIGHT PATH CONSTRAINTS(ACCEL,,XLF,THETA),
C ALPHA WILL BE REDUCED ACCORDINGLY IN DERIV2,
C
1703 4 ALPHA = ALPHA + DADT*S(3)
1706 IF(XLF .LT. 0.9)ALPHA = ALPHA + DADT*S(3)
1712 IF(XLF .LT. 0.8)ALPHA = ALPHA + DADT*S(3)
1717 26 CONTINUE

C
C ROLL ANGLE CONTROL (26-49)
C
1717 IF(MROLL .EQ. 0)GO TO 49
1720 HEAD = S(6)*57.3
1722 IF(ROLL .GE. 2)GO TO 45
1725 DFLPST = ABS(PHI*PHI*GAOS*CY/(2.*DPHIDT**S(4)*COS(S(5))))
1740 IF(ABS(HEADF-HEAD) .LT. 57.3*DE(PHI)GO TO 45
1751 PHI = PHI + DPHIDT*S(3)
1753 IF(ABS(PHI) .GT. PHIMAX .AND. PHI .GT. 0.0)PHI = PHIMAX
1764 IF(ABS(PHI) .GT. PHIMAX .AND. PHI .LT. 0.0)PHI = -PHIMAX
1774 GO TO 49
1775 45 GO TO(46,47,49),IROLL
2004 46 IROLL = 2
2005 47 IF((ITURN .GT. 0 .AND. HEAD .GE. HEADF) .OR. (ITURN .LT. 0 .AND.
9HEAD .LT. HEADF))GO TO 48
2023 PHI = PHI - DPHIDT*S(3)
2026 IF(ABS(PHI) .LE. 2./57.3)PHI = ((HEADF-HEAD)/ABS(HEADF-HEAD))
9*2./57.3
2036 GO TO 49
2037 48 IROLL = 3
2040 PHI = 0.0
2041 S(6) = HEADF/57.3
2043 MROLL = 0
2044 49 CONTINUE

C
C MAKE INTEGRATION STEP
C
2044 3 CALL INTM(S,6,2,1.,1.,1.,1.,1.,1., DERIV2)
2056 IF(K .EQ. 99)GO TO 9
2064 T(5) = S(8)
2065 IF(I35 .EQ. 2)GO TO 22

C
C SAVE VALUES FOR OBSTACLE HEIGHT INTERPOLATION
C
2067 IF((S(7) = HAPT) .GE. HDT)GO TO 21
2073 VJ = S(4)
2074 TJ5 = T(5)
2075 HJ = S(7)
2077 GO TO 22

C
C FIND VALUES AT OBSTACLE HEIGHT (21-1015)
C
2100 21 I35 = 2
2101 S35 = VVV(HDT,TJ5,T(5),HJ,S(7))
2111 V35 = VVV(HDT,VJ,S(4),HJ,S(7))*SQRT(ANS(7))*0.592087

```

## TAKOFF

```

2130      IF(IDCN .EQ. 9)
          +WRITE(6,1015)S35,V35
1015 FORMAT(30H DISTANCE TO OBSTACLE HEIGHT =,F7,1,20H SCREEN SPEED(EAS
          9) =,F6,1)
2151      22 IF(IG .EQ. 2)GO TO 25
2153      IF(IG .EQ. 1)GO TO 23
C
C      GEAR RETRACTION (22-23)
C
2155      IF((S(7) - HAPT) .LT. HGR)GO TO 25
2160      TG = S(2)
2161      TGU = S(2) + DTGR
2163      IF(IDCN .EQ. 9)
          +WRITE(6,1025)TG,TGU
1025 FORMAT(1X,27HGEAR RETRACTION STARTED AT ,F6,1,17H SEC,COMPLETE AT
          9,F6,1,4H SEC)
2200      IG = 1
C
C      GEAR DRAG INCREMENT REDUCED LINEARLY WITH TIME IN DTGR SECONDS
C
2201      23 GRCD = CDGFR*(1.0 - (S(2) - TG)/DTGR)
2205      IF(GRCD .GE. 0.0)GO TO 25
2207      GRCD = 0.0
2210      IG = 2
2211      25 CONTINUE
2211      IF(JROUTE .EQ. 2)GO TO 39
C
C      FLAP RETRACTION (25-16)
C
2213      IF(DEFLD .EQ. 0.0)GO TO 16
2214      GO TO(10,15),MFLAP
2222      10 IF((S(7) - HAPT) .LT. MFLAP .OR. S(4)*SQRT(ANS(7))* .592087 .LT.
          9 VFLAP)GO TO 16
2244      MFLAP = 2
2244      TIME = (DEFLD - XDEFLD(IFLAP))/DFLPT
2250      IF(IDCN .EQ. 9)
          +WRITE(6,1030)XDEFLD(IFLAP),TIME
1030 FORMAT(1X,19HFLAPS RETRACTED TO ,F4,1,9H DEG, IN ,F4,1,5H SEC.)
2267      15 DEFLD = DEFLD - DFLPT*S(3)
2272      IF(DEFLD .GT. XDEFLD(IFLAP))GO TO 16
2276      DEFLD = XDEFLD(IFLAP)
2300      MFLAP = 1
2300      IFLAP = IFLAP + 1
2302      MFLAP = XMFLAP(IFLAP)
2304      VFLAP = XVFLAP(IFLAP)
C
C      VECTORED THRUST ANGLE REDUCTION (16-56)
C
2307      16 CONTINUE
2307      IF(ANGLE .EQ. 0.0)GO TO 56
2310      GO TO(50,55),HVECT
2316      50 IF((S(7) - HAPT) .LT. HVECT .OR. S(4)*SQRT(ANS(7))* VELFTR .LT.
          9 VVECT)GO TO 56
2340      HVECT = 2
2340      TIME = (ANGLE - XHVECT)/DTVECT
2344      IF(IDCN .EQ. 9)

```

## TAKOFF

```

      +WRITE(6,1055)XNU(IVECT),TIME
1055 FORMAT(1X,33HVECTORED THRUST ANGLE REDUCED TO ,F4.1,9H DEG, IN ,
      9F4.1,5H SEC.)
2363 55 ANGLE = ANGLE - DTVECT*S(3)
2366 IF (ANGLE .GT. XNU(IVECT))GO TO 56
2372 ANGLE = XNU(IVECT)
2374 HVECT = 1
2374 IVECT = IVECT + 1
2376 HVECT = XHVECT(IVECT)
2400 VVECT = XVVECT(IVECT)

C
C THROTTLE SETTING MANAGEMENT (56-39)
C
2403 56 CONTINUE
2403 GO TO(31,32,33),IPOWER
2412 31 IF((S(7) = HAPT) .LT. MPOWER .OR. S(4)*SQRT(ANS(7))* VELFTR .LT.
      9 VPOWER)GO TO 39

C
C DETERMINE POWER INCREASE OR DECREASE
C
2434 IF(PWRSET = XPOWER(MPOWER))34,39,35

C
C ADVANCE THROTTLE SETTING LOOP (34-35)
C
2441 34 IPOWER = 2
2441 TIME = 100.*(XPOWER(MPOWER) - PWRSET)/DTPUP
2445 SET = XPOWER(MPOWER)*100.
2446 IF(IDCN .EQ. 9)
      +WRITE(6,1050)SET,TIME
1050 FORMAT(1X,28HADVANCE THROTTLE SETTING TO ,F6.1,12H PERCENT IN ,
      9F4.1,5H SEC.)
2464 32 PWRSET = PWRSET + (DTPUP/100.)*S(3)
2470 IF(PWRSET .LT. XPOWER(MPOWER))GO TO 39
2473 PWRSET = XPOWER(MPOWER)
2475 MPOWER = MPOWER + 1
2477 HPOWER = XHPR(MPOWER)
2501 VPOWER = XVPR(MPOWER)
2503 IPOWER = 1
2504 GO TO 39

C
C RETARD THROTTLE SETTING LOOP (35-39)
C
2507 35 IPOWER = 3
2507 TIME = 100.*(PWRSET - XPOWER(MPOWER))/DTPDWN
2513 SET = XPOWER(MPOWER)*100.
2514 IF(IDCN .EQ. 9)
      +WRITE(6,1051)SET,TIME
1051 FORMAT(1X,27HRETARD THROTTLE SETTING TO ,F5.1,12H PERCENT IN ,F4.1
      9,5H SEC.)
2532 33 PWRSET = PWRSET - (DTPDWN/100.)*S(3)
2536 IF(PWRSET .GT. XPOWER(MPOWER))GO TO 39
2542 PWRSET = XPOWER(MPOWER)
2544 MPOWER = MPOWER + 1
2545 HPOWER = XHPR(MPOWER)
2547 VPOWER = XVPR(MPOWER)
2552 IPOWER = 1

```

## TAKOFF

```

2553      39 CONTINUE
      C
      C   HEADING CONTROL (39-69)
      C
2553      TRACK = SQRT(S(8)*S(8) + S(9)*S(9))
2557      IF((S(7) - HAPT) .GE. HHEAD .OR. TRACK .GE. RANGE)GO TO 61
2576      GO TO 69
2576      61 MROLL = 1
2577      IROLL = 1
2600      HEADF = XHEAD(IHEAD)
2602      IF(IDCN .EQ. 9)WRITE(6,66)HEADF
2602      66 FORMAT(1X,22HBEGIN TURN TO HEADING ,F5.1,5H DEG,.)
2616      IHEAD = IHEAD + 1
2620      RANGE = XRANGE(IHEAD)*RNGFTR
2622      HHEAD = XHHEAD(IHEAD)
2625      HEAD = S(6)*57.3
2627      ITURN = 1
2630      IF(HEADF .LT. HEAD)ITURN = -1
2634      DPHIOT = FLOAT(ITURN)*ROLRAT/57.3
2637      69 CONTINUE
2637      IF(NCOUNT .LT. 10)GO TO 2
2642      NCOUNT = 0
2642      XDADI = (ALPHA - ALPHAJ)/S(3)
2645      DTHTDT = (THETAJ - THETAJ)/S(3)
2647      TA = ENP * THRUST
2651      VKTS = S(4)*VELFTR
2654      EAS = VKTS*SQRT(ANS(7))
2660      GAMMA = S(5)*57.295
2662      ROC = S(4)*SIN(S(5))*60.
2671      ROLL = PHI*57.3
2672      HEAD = S(6)*57.3
2674      IF(IDCN .EQ. 9)
+WRITE(6,1002)S(2),S(8),S(9),S(7),VKTS,EAS,EM,S(10),CL,CD,ALPHA,
+GAMMA,ROC,XLF,TA,THETAJ,ROLL,HEAD
2762      IPAGE = IPAGE + 1
2764      IF(IPAGE .LT. MPAGE)GO TO 2
2766      IPAGE = 0
2766      IF(IDCN .EQ. 9)
+WRITE(6,998)
2777      IF(IUCN .EQ. 9 .AND. IUNIT .EQ. 1)WRITE(6,1000)
3015      IF(IDCN .EQ. 9 .AND. IUNIT .EQ. 2)WRITE(6,2000)
      C
      C   END OF MAIN AIRBORNE INTEGRATION LOOP.
      C
3033      GO TO 2
      C
      C   CONVERSIONS AND PRINT OUT.
      C
3034      B TA = ENP * THRUST
3036      VKTS = S(4)*VELFTR
3040      EAS = VKTS*SQRT(ANS(7))
3044      IF(KODE .NE. 3)EAS = VEND
3054      GAMMA = S(5)*57.295
3056      ROC = S(4)*SIN(S(5))*60.
3064      ROLL = PHI*57.3
3065      HEAD = S(6)*57.3

```

```

TAKOFF
3067      IF(IDCN ,EQ. 9)
          +WRITE(6,1002)S(2),S(8),S(9),S(7),VKTS,EAS,EM,S(10),CL,CD,ALPHA,
          9GAMMA,ROC,XLF,TA,THETA,ROLL,HEAD
3155      WRITE(6,1052)
3161      IF(KODE ,EQ. 2)WRITE(6,1053)
3176      IF(KODE ,EQ. 3)WRITE(6,1054)
1052      FORMAT(/,1X,14HEND OF TAKOFF)
1053      FORMAT(1X,46HROTATING REQUIRED TO MAINTAIN CONSTANT SPEED)
1054      FORMAT(1X,59HDESIRED END SPEED NOT ATTAINABLE AT SPECIFIED POWER S
          9ETTING)
3210      RETURN
3211      9 CONTINUE
3211      IF(RTCL ,GT. ROC)WRITE(6,996)
          996      FORMAT(/,2X,66Hcannot ACCEL, AT INPUT R/C (RTCL), TRY VALUE .LT. L
          9AST R/C PRINTED)
3223      WRITE(6,997)
          997      FORMAT(/,1X,38H*** ABNORMAL TERMINATION OF TAKOFF ***))
3233      RETURN
3233      END

```

#### SUBPROGRAM LENGTH

04564

FUNCTION ASSIGNMENTS  
YYY = 000020

#### STATEMENT ASSIGNMENTS

1	= 000770	2	= 001425	3	= 002045	4	= 001704	5	= 000037	6	= 000127
7	= 000150	8	= 003035	9	= 003212	10	= 002223	15	= 002270	16	= 002310
21	= 002101	22	= 002152	23	= 002202	25	= 002212	26	= 001720	27	= 001600
28	= 001547	29	= 001575	31	= 002413	32	= 002465	33	= 002533	34	= 002440
35	= 002506	39	= 002554	41	= 001635	42	= 001644	43	= 001665	44	= 001701
45	= 001776	46	= 002005	47	= 002006	48	= 002040	49	= 002045	50	= 002317
55	= 002364	56	= 002404	61	= 002577	66	= 004210	69	= 002640	101	= 001013
102	= 001057	103	= 001050	106	= 001000	110	= 001061	113	= 001134	120	= 001312
201	= 003454	202	= 003466	203	= 003504	204	= 003513	205	= 003531	206	= 003557
207	= 003600	208	= 003607	209	= 003616	210	= 003622	211	= 003626	212	= 003635
213	= 003644	214	= 003656	215	= 003663	216	= 003667	217	= 003673	299	= 000560
300	= 001455	500	= 003434	501	= 000102	996	= 004244	997	= 004255	998	= 003733
999	= 003677	1000	= 003753	1002	= 004045	1009	= 003710	1010	= 003740	1015	= 004117
1025	= 004130	1030	= 004143	1040	= 004066	1050	= 004164	1051	= 004176	1052	= 004221
1053	= 004225	1054	= 004234	1055	= 004152	1056	= 004102	1057	= 003725	2000	= 004010

#### BLOCK NAMES AND LENGTHS

UNIV = 000039/01 AERO = 000020/02 ROLL = 000002/03 FXCHNG = 000004/04 XROLL = 000041/05 XFLATE = 000121/06  
UNIT = 000002/07

#### VARIABLE ASSIGNMENTS

ALPHA = 000010/02	ALPHAJ = 004522	ANGLE = 000005/02	ANS = 004323	CD = 000014/02	CDGEAR = 004427
CDGFTF = 004462	CL = 000013/02	CY = 000012/02	DADT = 004454	DELFD = 000006/02	DELPST = 004546
DFLPOT = 004430	DPHIDT = 004547	DSTOP = 004461	DABS = 004431	DTGR = 004432	DTHTDT = 004527
DTPDOWN = 004433	DTPUP = 004434	DTVECT = 004435	EAS = 004525	EASTO = 004531	EM = 000010/01
ENP = 000021/01	ENPOUT = 004532	EYEW = 000020/01	EYEWNG = 004436	G = 000001/07	GAMMA = 004562

ROUTINE COMPILES IN 060200

DERIV1

SUBROUTINE DERIV1

C  
C SUBROUTINE DERIV1 COMPUTES THE ACCELERATION T(6) FOR THE GROUND ROLL  
C

```

      REAL MU
      COMMON /UNIV/ NPC ,MSC ,IDC ,H ,ST ,R ,W ,
      1WF ,FM ,VMO ,EMMO ,ALPHLO,CLALPH,SW ,AR ,B ,
      2EYEW ,ENP ,TA ,WC ,WGS ,KWRITE,OLMC4
      3,KSIZE
      COMMON /AERO/ VEL,QS,HABS,THRUST,TVECT, ANGLE,DELF,DELSPL,ALPHA,
      9CX,CY,CL,CD,RHO,GRCD,IFAST
      COMMON /XROLL/T(30),REQ,MU,NREV
      COMMON /UNIT/IUNIT,G
      QS = 0.5*RHO*SW*T(4)*T(4)
      IF(QS.EQ. 0.)QS = 0.1
      IFAST = 1
      CALL AKODYA
      T(6) = (G/W)*(-W*MU + QS*(CY*MU - CX))
      T(7) = T(4)
      RETURN
      END
  
```

SUBPROGRAM LENGTH

00040

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

BLOCK NAMES AND LENGTHS

UNIV - 000030/01 AERO - 000020/02 XROLL - 000041/03 UNIT - 000002/04

VARIABLE ASSIGNMENTS

CX - 000011/02 CY - 000012/02 G - 000001/04 IFAST - 000017/02 MU - 000037/03 QS - 000001/02  
RHO - 000015/02 SW - 000015/01 T - 000000/03 W - 000006/01

START OF CONSTANTS-000025 TEMPS--000030 INDIRECTS-000040

7600 COMPILATION -- RUN76 LEVEL 9H 74/07/15.

ROUTINE COMPILES IN 044000



# DERIV2

```

      SUBROUTINE DERIV2
C     SUBROUTINE DERIV2 COMPUTES THE TIME DERIVATIVES FOR THE AIRBORNE
C     PORTION OF THE TAKEOFF AND MANAGES THE FLIGHT PATH CONTROL,
C
      COMMON /UNIV/ NPC ,NSC ,IDC ,H ,ST ,R ,M ,
      1WF ,EM ,VMO ,EMMO ,ALPHLO,CLALPH,SW ,AR ,B ,
      2EYEW ,ENP ,TA ,WG ,WGS ,KWRITE,DLMC4
      3,KSIZE
      COMMON /AERO/ VEL,DS,HABS,THRUST,IVECT, ANGLE,DELF,DELSPL,ALPHA,
      9CX,CY,CL,CD,RHD,GRCD,IFAST
      COMMON /XFLATE/ S(75),ROC,THEMAX,THETAF,XLF,XLFMAX,K
      COMMON /ROLL/ PHI,ROCMIN
      COMMON /UNIT/ IUNIT,G
      NER = 1
      2   QS = 0.5*RHD*S**S(4)*S(4)
      5   VKTS = S(4)*0.592087
      7   IF(IUNIT .EQ. 2)VKTS = S(4)
C
C     CONSTANT RATE OF CLIMB PORTION
C
      13  1 IF(K .EQ. 9)CALL CLIMB(ROC,S(5),VKTS,NER)
      20  IF(NER .NE. 1)WRITE(6,666)ALPHA,ROC
      666 FORMAT(1X,30H**ERROR IN CLIMB = ALPHA,ROC =,2F10,2)
      32  26 IFAST = 0
      33  CALL ARODYN
C
C     CHECK FUSELAGE ANGLE. IF THETAF .GT. THEMAX, REDUCE ALPHA (261=262)
C
      34  261 THETAF = S(5)*57.295 + ALPHA - EYEW
      40  IF(THETAF .IF. THEMAX)GO TO 262
      42  ALPHA = THEMAX + EYEW - S(5)*57.295
      45  GO TO 26
C
C     CHECK LOAD FACTOR. IF XLF .GT. XLFMAX, REDUCE ALPHA (262=263)
C
      45  262 XLF = (QS*CY)/W
      47  IF(XLF .LE. XLFMAX)GO TO 263
      52  ALPHA = ALPHA - 0.05
      54  GO TO 26
C
C     CHECK ACCELERATION. IF S(10).LT. 0.0, REDUCE ALPHA (263=30)
C     IF IN CONSTANT RATE OF CLIMB, REDUCE ROLL ANGLE (MIN OF 5.0)
C
      55  263 S(10) = (G/W)*(-CX*QS - W*SIN(S(5)))
      64  IF(S(10).GE. 0.0)GO TO 30
      66  IF(K .EQ. 9)GO TO 264
      70  265 ALPHA = ALPHA - 0.05
      72  IF(ALPHA .LT. -15.0)GO TO 99
      74  GO TO 26
      75  264 IF(ABS(PHI) .LT. 5.0/57.3)GO TO 265
      101  IF(PHI .GT. 0.)PHI = PHI - 0.1/57.3
      103  IF(PHI .LT. 0.)PHI = PHI + 0.1/57.3
      106  GO TO 1
      107  30 CONTINUE
      107  ARG = W*CD(S(5))/(CY*QS)
      115  IF(ARG .GT. 1.00)ARG = 1.00

```

```

DERIV2
121      IF (ABS(PHI) .GT. 0. .AND. S(4)*SIN(S(5))*60. .LT. ROCMIN) PHI =
      +(PHI/ABS(PHI))*ACOS(ARG)
142      S(11) = (G/(W*S(4)))*(CY*QS*COS(PHI) - W*COS(S(5)))
154      IF (S(11)*57.3 .GE. -1.0) GO TO 40
160      IF (PHI .EQ. 0.) GO TO 40
161      IF (PHI .LT. 0.) PHI = PHI + 0.1/57.3
164      IF (PHI .GT. 0.) PHI = PHI - 0.1/57.3
167      IF (ABS(PHI) .LT. 0.15/57.3) PHI = 0.
173      GO TO 30
174      40 S(12) = (G/(W*S(4)*COS(S(5))))*(CY*QS*SIN(PHI))
206      S(13) = S(4)*SIN(S(5))
211      S(14) = S(4)*COS(S(5))*COS(S(6))
217      S(15) = S(4)*COS(S(5))*SIN(S(6))
226      RETURN
226      99 WRITE(6,66)S(8)
235      66 FORMAT(1X,46H*** UNABLE TO MAINTAIN ACCEL. ,GE. 0.0, DV/DT=,F9.5)
236      K = 99
      END

```

#### SUBPROGRAM LENGTH

00347

#### FUNCTION ASSIGNMENTS

##### STATEMENT ASSIGNMENTS

1	= 000014	26	= 000033	30	= 000110	40	= 000175	66	= 000270	99	= 000227
261	= 000035	262	= 000046	263	= 000056	264	= 000076	265	= 000071	666	= 000245

##### BLOCK NAMES AND LENGTHS

UNIV	= 000030/01	AERO	= 000020/02	XFLATE	= 000121/03	ROLL	= 000002/04	UNIT	= 000002/05
------	-------------	------	-------------	--------	-------------	------	-------------	------	-------------

##### VARIABLE ASSIGNMENTS

ALPHA	= 000010/02	ARG	= 000346	CX	= 000011/02	CY	= 000012/02	EYEW	= 000020/01	G	= 000001/05
IFAST	= 000017/02	IUNIT	= 000000/05	K	= 000120/03	NER	= 000344	PHI	= 000000/04	QS	= 000001/02
RHO	= 000015/02	ROC	= 000113/03	ROCMIN	= 000001/04	S	= 000000/03	SW	= 000015/01	THEMAX	= 000114/03
THETAF	= 000115/03	VKTS	= 000345	W	= 000006/01	XLF	= 000116/03	XLFMAX	= 000117/03		

START OF CONSTANTS=000241      TEMPS--000300      INDIRECTS=000336

7600 COMPILATION -- RUN7A LEVEL 98      74/07/15,

ROUTINE COMPILES IN 044300

## CLIMB

```

SUBROUTINE CLIMB(ROC,GAMMA,VKTS,NER)
C
C SUBROUTINE CLIMB FINDS THE REQUIRED ALPHA TO FLY AT THE CONSTANT
C RATE OF CLIMB RTCL, GIVEN THE THRUST AND VELOCITY. CHANGES IN FLIGHT
C PATH ANGLE ARE FAIRLY INSENSITIVE TO VARIATIONS IN ANGLE OF ATTACK,
C AS A RESULT, THE COMPUTED RATE OF CLIMB WILL DIFFER SOME (USUALLY LOWER)
C THAN THE DESIRED VALUE RTCL.
C SUBROUTINE ZERJVB IS A ZERO-FINDER,
C
      REAL NU
      COMMON /UNIV/ NPC ,NSC ,IDC ,W ,ST ,R ,W ,
      1WF ,EM ,VMO ,EMMO ,ALPHLO,CLALPH,SW ,AR ,B ,
      2EYEW ,ENP ,TA ,WG ,WGS ,KWRITE,DLMC4
      3,KSIZE
      COMMON /AERO/ VEL,QS,HABS,THRUST,TVECT, ANGLE,DELFD,DELSPL,ALPHA,
      9CX,CY,CL,CD,RHO,GRCD,IFAST
      COMMON /ROLL/ PHI,ROCHIN
      COMMON /UNIT/IUNIT,G
      NER = 1
      6 TOL = 0.01
      7 STEP = 1.0
      11 JX = 0
      11 JC = 0
      12 FACTOR = 2.8561
      14 IF(IUNIT .EQ. 2)FACTOR = 1.00
      17 QS = 0.5*RH0*VKTS*VKTS*SW*FACTOR
      23 ERROR = 999.
      25 40 IF(JX .EQ. 0)ERRM1 = ERROR
      30 IFAST = 0
      31 CALL ARODYN
      32 ALPHX = ALPHA*.017453
      34 ERROR = QS*(CY*COS(GAMMA)*COS(PHI) - CX*SIN(GAMMA)) - W
      40 IF(ABS(ERROR) .LT. 0.0025)GO TO 60
      46 IF(JX .EQ. 2)GO TO 60
      70 CALL ZERJVB(ERROR,ERRM1,ALPHA,STEP,TOL,JC,JX)
      76 IF(JC .GT. 25)GO TO 65
      104 GO TO 40
      104 60 RETURN
      105 65 NER = 9
      106 RETURN
      107 END

```

## SUBPROGRAM LENGTH

00147

## FUNCTION ASSIGNMENTS

## STATEMENT ASSIGNMENTS

40 = 000026 60 = 000105 65 = 000106

## BLOCK NAMES AND LENGTHS

UNIV = 000030/01 AERO = 000020/02 ROLL = 000002/03 UNIT = 000002/04

# CLIMB

## VARIABLE ASSIGNMENTS

ALPHA = 000010/02	ALPHX = 000146	CX = 000011/02	CY = 000012/02	ERRM1 = 000145	ERROR = 000144
FACTOR = 000143	IFAST = 000017/02	TUNIT = 000000/04	JC = 000142	JX = 000141	NU = 000136
PHI = 000000/03	QS = 000001/02	RHO = 000015/02	STEP = 000140	SW = 000015/01	TOL = 000137
W = 000006/01					

START OF CONSTANTS=000112      TEMPS--000122      INDIRECTS=000136

7600 COMPILATION -- RUN76 LEVEL 9B      74/07/15.

ROUTINE COMPILES IN 044000

# PULLUP

SUBROUTINE PULLUP(DADT,KODE,PHRSET,KENG,VEND,HAPT,DABS)

C  
C SUBROUTINE PULLUP DETERMINES THE TIME RATE OF CHANGE OF THE ANGLE OF  
C ATTACK DADT REQUIRED TO BRING THE AIRCRAFT FROM THE CONSTANT RATE OF  
C CLIMB TO THE FINAL CLIMB SPEED(I,E, REDUCE ACCELERATION ALONG FLIGHT  
C PATH TO ZERO AND THUS INCREASING FLIGHT PATH ANGLE). THE PULLUP  
C MANEUVER STARTS AT SPEED OF VEND = PHARG\*VEND(E,G, VEND=250., PHARG=0.04,  
C = START OF PULLUP AT 240, KNOTS). THE SUBROUTINE DOES THE VERY SAME  
C INTEGRATION LOOP AS TAKEOFF, WITHOUT ANY PRINT OUT, AND VARIES THE  
C VALUE OF DADT UNTIL PROPER VALUE FOUND. THE SEARCH FOR THE REQUIRED  
C DADT IS FOUND BY A BISECTION TECHNIQUE.  
C  
C IF PULLUP FAILS WITH DADT=4.0 (MAX. VALUE ALLOWED), USER SHOULD INPUT  
C LARGER VALUE FOR PHARG. THE PROGRAM WILL GENERALLY OVER-SHOOT THE  
C END SPEED BY A KNOT OR SO.

EXTERNAL DERIV2  
COMMON /UNIV/ NPC ,NSC ,IDC ,H ,ST ,R ,W ,  
1WF ,FM ,VMO ,EMMO ,ALPHLO,CLALPH,SW ,AR ,B ,  
2EYEW ,FNP ,TA ,WG ,WGS ,KWRITE,DLMC4  
3,KSIZE  
COMMON /AFRO/ VEL,OS,HABS,THRUST,TVECT, ANGLE,DELF,DELSPL,ALPHA,  
9CX,CY,CL,CD,RHD,GRCD,IFAST  
COMMON /XFLATE/ S(75),ROC,THEMAX,THETA,CLF,XLFMAX,K  
COMMON /UNIT/UNIT,G  
DIMENSION ANS(8)

VELFTR = 0.592087

IF(UNIT.EQ. 2)VELFTR = 1.00

S2J = S(2)

S4J = S(4)

S5J = S(5)

S6J = S(6)

S7J = S(7)

S8J = S(8)

S9J = S(9)

WJ = W

ALPHAJ = ALPHA

KODE = 1

ILOOP = 0

DADT = 4.0

DADTIG = 0.0

ITIME = 1

50 ILOOP = ILOOP + 1

IF(ILOOP.GT. 15) GO TO 95

ISTART = 1

51 S(2) = S2J

S(4) = S4J

S(5) = S5J

S(6) = S6J

S(7) = S7J

S(8) = S8J

S(9) = S9J

W = WJ

ALPHA = ALPHAJ

300 CALL ATMOS(S(7),DABS,ANS)

9A = ANS(4)

# PULLUP

```

76      RHO = ANS(3)
77      EM = S(4)/SA
101     HABBS = S(7) = HAPT
103     CALL ENGINE(S(7),DTABS,EM,PWRSET,WF,KENG)
112     IF(ISTART,ME,2)
113     9CALL INTS(S,6,2,1,,1,,1,,1,,1,,1,, DERIV2)
131     IF(ISTART,EQ,3)RETURN
140     ISTART = 2
141     W = W - WF*ENP*S(3)/3600,
145     K = 1
146     ALPHA = ALPHA + DADT*S(3)
150     IF(XLF,LT,0.9)ALPHA = ALPHA + DADT*S(3)
154     IF(XLF,LT,0.8)ALPHA = ALPHA + DADT*S(3)
161     CALL INTM(S,6,2,1,,1,,1,,1,,1,,1,, DERIV2)
173     EAS = S(4)*SQRT(ANS(7))*VELFTR

C
C      TEST FOR VARIOUS END CONDITIONS ( =110)
C
200     IF(S(10),LT,0.02)GO TO 100
207     IF(EAS,GE,VEND + 0.5,AND,ITIME,EQ,1)GO TO 100
220     GO TO 300
220     100 IF(ITIME,EQ,2)GO TO 101
222     IF(S(10),GT,0.02,AND,EAS,GE,VEND + 0.5)GO TO 150
235     ITIME = 2
236     101 IF(DADT,LT,0.03)GO TO 160
241     IF(EAS,GT,VEND,AND,EAS,LT,VEND + 1.0)GO TO 200
252     IF(EAS,LT,VEND)GO TO 110
253     IF(DADT,EQ,4.0)GO TO 99
255     DADTLO = DADT
256     GO TO 115
256     110 DADTUP = DADT
257     115 DADT = 0.5*(DADTUP + DADTLO)
262     GO TO 50

C
C      KODE = 2 END SPEED REACHED, BUT TOO MUCH THRUST AVAILABLE = THROTTLING
C      WILL BE REQUIRED.
C      KODE = 3 = CANNOT REACH DESIRED END SPEED AT SPECIFIED POWER SETTING =
C      PULLUP DONE TO ZERO ACCELERATION
C      KODE = 9 = PROGRAM FAILS
C
262     150 KODE = 2
263     GO TO 200
264     160 KODE = 3
265     200 ISTART = 3
266     GO TO 51
267     99 WRITE(6,9A)
267     98 FORMAT(1X,44H*** FAILED IN PULLUP - TRY INPUT PMARG = 0.1)
277     KODE = 9
300     RETURN
300     95 WRITE(6,96)
300     96 FORMAT(1X,29H*** EXCESSIVE LOOPS IN PULLUP)
310     KODE = 9
311     RETURN
311     END

```

PULLUP

SUBPROGRAM LENGTH

00406

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

50	= 000041	51	= 000047	95	= 000301	96	= 000340	98	= 000331	99	= 000270
100	= 000221	101	= 000257	110	= 000257	115	= 000260	150	= 000263	160	= 000265
200	= 000266	300	= 000065								

BLOCK NAMES AND LENGTHS

UNIV = 000030/01 AERO = 000020/02 XFLATE = 000121/03 UNIT = 000002/04

VARIABLE ASSIGNMENTS

ALPHA	= 000010/02	ALPHAJ	= 000376	ANS	= 000354	DADTLO	= 000400	DADTUP	= 000405	DTAB5	= 000000
EAS	= 000404	EM	= 000010/01	ENP	= 000021/01	FACTOR	= 000365	HABS	= 000002/02	ILOOP	= 000377
ISTART	= 000402	ITIME	= 000401	IUNIT	= 000000/04	K	= 000120/03	RHO	= 000015/02	S	= 000000/03
BA	= 000403	S2J	= 000366	S4J	= 000367	S5J	= 000370	S6J	= 000371	S7J	= 000372
S8J	= 000373	S9J	= 000374	VELFTR	= 000364	W	= 000006/01	WF	= 000007/01	WJ	= 000375
XLF	= 000116/03										

START OF CONSTANTS-000314 TEMPS--000345 INDIRECTS-000353

7600 COMPILATION -- RUN76 LEVEL 9B 74/07/15.

ROUTINE COMPILES IN 044600

ZERJVB

```

SUBROUTINE ZERJVB(ERROR,ERRM1,DRIVER,STEP,TOL,JC,JX)
ERR = ERROR
11 IF(JC,GT,0)GO TO 10
14 JM=0
14 JP=0
15 JF=0
15 JX=0
16 JA=0
17 10 JC=JC+1
20 IF(JP,GT,0)GO TO 20
23 12 JP=JP+1
25 ORM1=DRIVER
25 DRIVER = DRIVER + STEP
27 15 RETURN
30 20 CONTINUE
30 IF(JF,GT,0)GO TO 45
33 IF(ERRM1,LT,0.,AND,FRR,GT,0.)GO TO 30
41 IF(FRRM1,GT,0.,AND,ERR,LT,0.)GO TO 30
47 IF(ERR,LT,0.)GO TO 25
50 IF(JM,GT,0)GO TO 22
52 IF(ERR,GT,ERRM1)GO TO 22
54 GO TO 12
54 22 BU=DRIVER
55 ORM1=DRIVER
56 DRIVER = BU - STEP
57 JM=JM+1
61 GO TO 15
61 25 IF(JM,GT,0)GO TO 22
64 IF(ERR,LT,ERRM1)GO TO 22
66 GO TO 12
66 30 IF(ORM1,GT,DRIVER)GO TO 35
72 BL=ORM1
72 HU=DRIVER
74 GO TO 40
74 35 RU=ORM1
75 BL=DRIVER
76 ERRM1 = ERROR
100 40 JX = 1
101 IF(JF,GT,0)GO TO 45
104 JF = JF + 1
105 DRIVER = BL + 0.5 * (HU - BL)
110 RETURN
111 45 IF(ERROR * ERRM1 .LE. 0.0) GO TO 46
113 BL = DRIVER
114 ERRM1 = ERROR
115 GO TO 47
116 46 HU = DRIVER
117 47 DRIVER = BL + 0.5 * (HU - BL)
122 IF(ABS(BU - BL) ,LT, TOL)JX = 2
127 RETURN
130 END

```

SUBPROGRAM LENGTH



ZERJVB

00153

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

10	= 000020	12	= 000024	15	= 000030	20	= 000031	22	= 000055	25	= 000062
30	= 000067	35	= 000075	40	= 000101	45	= 000112	46	= 000117	47	= 000120

BLOCK NAMES AND LENGTHS

VARIABLE ASSIGNMENTS

BL	= 000152	BU	= 000151	DRM1	= 000150	ERR	= 000143	JA	= 000147	JF	= 000146
JM	= 000144	JP	= 000145	JX	= 000000						

START OF CONSTANTS=000133      TEMPS--000135      INDIRECTS=000143

7600 COMPILATION -- RUN76 LEVEL 9B      74/07/15.

ROUTINE COMPILES IN 044000

# ATMOS

```

      SUBROUTINE ATMOS(HH,DTABS,ANS)
      COMMON /UNIT/IUNIT,G
      DIMENSION ANS(8)
      C HH=ALTITUDE IN FEET
      C DTABS=TEMPERATURE INCREMENT FROM STANDARD TEMPERATURE
      C ANS(1)=TEMPERATURE (RANKINE)
      C ANS(2)=PRESSURE (PSF)
      C ANS(3)=DENSITY (SLUG/FT3)
      C ANS(4)=SPEED OF SOUND IN FT./SEC.
      C ANS(5)=KINEMATIC VISCOSITY (FT2/SEC)
      C ANS(6)=PRESSURE RATIO
      C ANS(7)=DENSITY RATIO
      C ANS(8)=TEMPERATURE RATIO
      HJ = HH
      IF(IUNIT .EQ. 2)HJ = HJ / 0.3048
      DTABJ = DTABS
      IF(IUNIT .EQ. 2)DTABJ = DTABJ*(9./5.)
      THETA = 1.-.000006875*HJ + DTABJ/518.67
      DELTA = (1.-.000006875*HJ)**5.2561
      IF (HJ.LE.36089.) GO TO 4
      THETA = .7519 + DTABJ/518.67
      DELTA = .22336*EXP((36089.-HJ)/20786.)
      4 SIGMA = DELTA/THETA
      ANS(1) = THETA * 518.67
      ANS(2) = DELTA * 2116.22
      ANS(3) = SIGMA * .0023769
      ANS(4) = 1117.061 *SQRT(THETA )
      P = ANS(2)/144
      ANS(5) = .270558E+06*ANS(1)*SQRT(ANS(1))/(P*(1.+198.72/ANS(1)))
      ANS(6) = DELTA
      ANS(7) = SIGMA
      ANS(8) = THETA
      IF(IUNIT .EQ. 1)RETURN
      ANS(3) = ANS(3)*515.38
      ANS(4) = ANS(4)*0.3048
      RETURN
      END

```

SUBPROGRAM LENGTH

00172

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

4 - 000044

BLOCK NAMES AND LENGTHS

UNIT - 000002/01

VARIABLE ASSIGNMENTS

DELTA = 000167 DTABJ = 000165 HJ = 000164 IUNIT = 000000/01 P = 000171 SIGMA = 000170  
 THETA = 000166